R E & A
U.S.A. 146

Mosquito News

Published Quarterly
by the
AMERICAN MOSQUITO CONTROL ASSOCIATION, INC.

VOLUME 17 DECEMBER, 1957 NUMBER 4

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Annual Meeting, February 23–26, 1958, Washington, D. C.

MOSQUITO NEWS

Official Publication of the American Mosquito Control Association, Inc.

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Published by

AMERICAN MOSQUITO CONTROL ASSOCIATION, INC.

Printed by

Boyd Printing Company, Inc., Albany, N. Y.

A quarterly journal published on the 20th of March, June, September and December. Devoted to the improvement and the sound extension of mosquito control and related work as a vital public health service.

SUBSCRIPTION RATES

$5.00 per Year (U. S. money), Single Copies, $1.75
Mailed without charge to members of the Association.

MEMBERSHIP DUES—$5.00

BUSINESS COMMUNICATIONS

Communications relating to editorial matters and manuscripts submitted for publication in MOSQUITO NEWS should be addressed to Donald L. Collins, Editor, MOSQUITO NEWS, New York State Museum, Albany, New York.

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THE AMERICAN MOSQUITO CONTROL ASSOCIATION, INC.

PAPERS AND PROCEEDINGS OF THE 13th ANNUAL MEETING

OF THE AMERICAN MOSQUITO CONTROL ASSOCIATION HELD JOINTLY WITH THE FLORIDA ANTI-MOSQUITO ASSOCIATION MIAMI BEACH, FLORIDA, APRIL 28–MAY 2, 1957

PART II

THE DISPERSAL OF *AEDES TAENIORHYNCHUS*

II. THE SECOND EXPERIMENT

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The mark-release-recapture experiment of August 1951 (Provost, 1952), was successful enough to encourage us to repeat it with modifications to (1) have the hatching time under control, (2) reduce the larval mortality and effect a better emergence, (3) allow the marked adults to emerge unconfined and fly away freely, and (4) attempt more refined methods of recovery. This second experiment was essentially a replication, nevertheless. It was carried out in June and July of 1952 in the same San Carlos Bay area of southwestern Florida with the work again centered on Sanibel Island. The report on the 1951 experiment should be consulted for background information.

Our present understanding of dispersal in *Aedes taeniorhynchus* has been delineated in two previous papers (Provost 1952, 1953). Essentially it assumes an initial migration which, as in other migratory insects, is an end in itself. After the migration, dispersal progresses as it does in non-migratory species, viz., as a result of flights for food, shelter, oviposition and so on, all of which purposive flights are designated appetential in accordance with the understanding or belief that all behavior is compounded of appetential and consummatory elements (Tinbergen, 1951).

For the basic life history and behavior of this mosquito the reader is referred to papers by Nielsen (in press), Nielsen and Nielsen (1953), Nielsen and Haeger (1955), and Haeger (1955).

A. PRODUCTION OF LARVAE

The experimental design called for concentrating two million early fourth-instar larvae in three wooden troughs, where 68 mc. of P^{32} supplied on allocation from the Isotopes Division of the U. S. Atomic Energy Commission, were to be introduced for marking, as in the 1951 experiment (q.v.). The larvae were to be produced by flooding a small swale containing a good egg deposit. This was attempted and failed for a variety of reasons, so we had to devise another scheme quickly. The swale which had produced larvae for the 1951 experiment was dry and sod flooding in pans showed that a considerable area of *Philoxerus* contained one to two thousand eggs per square foot. There was, however, no standing water within a mile. It was then, in a moment almost of desperation, that the plan was changed to bringing the sod (with eggs) to the water. The technique worked so well that it became the basic method for our experiments thereafter.

A 20-foot wide, clean, and deep roadside borrow-pit was selected as the hatching pool; it was some 200 feet east of the 1951 release point. An earth dam was built to isolate a 100-foot section which was then pumped dry and all fish removed. The *Philoxerus* sod in the egg-laden swale was then cut, in the manner of lawn turf being transplanted, and transported to the "nursery" a mile and a half away. Some 1500 square feet of sod were laid neatly on the bottom of the nursery pool between $09^h30'$ and $17^h00'$ on June 10. Water was immediately pumped in and by 19^h the sod was all flooded. The egg hatch was not all within the two hours of pumping; some hatching occurred from seepage water on the bottom all through the sod-laying interval. The best estimate of the cumulative hatch was that between 10^h and 17^h some 5 percent or 6 percent of the eventual hatch occurred, with nearly all of the remaining hatch coming between 17^h and 20^h.

It was clear that this technique offered excellent possibilities for the production of a controlled hatch. Many refinements were envisioned, but even the first use of the method had successfully yielded the desired number of larvae, about 2¼ million; about 94 percent of them hatched within a 3-hour interval, and all within a pool selected for later ease of transfer of larvae from "nursery" to wooden vats for P^{32} introduction.

B. MARKING WITH RADIOPHOSPHORUS

The larvae were transferred to the vats on June 14 between 06^h and 11^h when they were mostly 16 to 24 hours old as fourth instars. The three vats were close together, some ten feet from the edge of the nursery pool and elevated about three feet above the ground. Each of the 3′ x 6′ x 8″ tanks was half-filled with water from the pool. The larvae were then skimmed from the pool with nets made of gauze stretched tautly across 18″ x 36″ wooden frames. Whenever one of the nets had a good layer of larvae over most of it, it was brought to one of the tanks and gently inverted into the water. Four men in five hours were able thus to transfer 1,900,000 larvae to the tanks with little noticeable mortality.

By the time the P^{32} was introduced to the larvae at 11^h on June 14 it had decayed to a mere 37 millicuries. Two of the tanks, each with 600,000 larvae (3.5/ml), received 13 mc for a P^{32} dosage of .077 μc/ml or .022 μc/larva. The third tank, with 700,000 larvae, received 11 μc, giving a P^{32} dosage of .065 μc/ml or .016 μc/larva.

Although the larvae were fed ground dog biscuit on what we thought was a demand basis there was no appreciable increase in larval radioactivity after 24^h on June 14, indicating that most larvae fed for only 13 hours in the tanks. This, combined with rather low P^{32} dosage, resulted in mosquitoes consideraly less radioactive than those marked the previous year. The newly-emerged males averaged 500 CPM and females, 2,000 CPM.

C. DEVELOPMENT AND EMERGENCE

The temperature in the tanks, which were shaded by a canvas, remained between 73° and 83° F. with a mean of 78° during the pupal period. The first pupa of *Aedes taeniorhynchus* was noticed June 15 at 11^h. We were not able properly to time the pupation in the tanks; we can say only that it occurred during the night of June 15–16, with a peak somewhere near midnight.

The progress of the emergence was followed more precisely. It occurred in the afternoon of June 17, the first adult having appeared at 11^h. Hourly emergences were estimated very roughly as follows:

before 13^h	50,000	18^h–19^h	350,000
13^h–14^h	50,000	19^h–20^h	100,000
14^h–15^h	150,000	20^h–21^h	50,000
15^h–16^h	150,000	Total	1,400,000
16^h–17^h	200,000		
17^h–18^h	300,000	16^h–19^h = 850,000 or 61%	

Using 18h as the peak of emergence and midnight of June 15 as the peak of pupation, we have a probable pupal duration of 42 hours, which is reasonably close to the expected 44 hours at 78° (Nielsen and Haeger, 1955), considering the crudity of the determination. From hatching to emergence was an even week, but the larvae while in the nursery pool were in the open sun and developed at temperatures much above the 78° to which the pupae were limited.

On the day following the emergence, the animals remaining in the tanks were examined. They were virtually all fourth-instar larvae, indicating an exhaustion of food, for they would otherwise have been pupae. Aliquot counts of these remaining larvae indicated 334,000. Since there had occurred no noticeable mortality in the tanks, the total emergence was 1,560,000 or 82.4 percent of larvae marked. On June 19 the remaining larvae were still not pupating. Samples transferred to jars and fed did pupate, however, supporting our belief that food in the tanks ran out shortly after the larvae were placed in them, and those larvae which had not completed their feeding period by then did not thereafter even become prepupae.

It was remarkable that so much of the emergence should have occurred on one day; the normal situation for "wild" broods is for the emergence to be spread over three to five days with a pronounced peak at the same hour each of those days (Nielsen and Haeger, 1955). It may be that the usual salt-marsh or mangrove breeding area exhibits a great variation in mean water temperatures, as affected by depth and sun exposure, and in quantity and availability of food. In the present experiment all these conditions were outstandingly uniform in the nursery pool. The excellent synchrony in emergence was further preserved by killing all remaining aquatic stages on June 19. Since no appreciable emergence had occurred on either June 18 or 19, all the marked population is known rather precisely to have emerged on June 17 between 13h and 21h with a peak around 18h.

D. RECOVERY TECHNIQUES

The dispersal of marked mosquitoes was studied, as in 1951, by identifying radioactive mosquitoes with a Geiger counter in collections made systematically for a month after the emergence.

Light Traps

Sixty-four light traps were operated nightly starting the night of departure, June 17/18, and continuing until mid-July. Their distribution (Fig. 1) was dictated by the lay of the land. One trap was at the departure point and four others were within a mile. Beyond a mile, the traps were set up along four main radii: (1) NW up the length of Sanibel Island and along the outer islands to Placida back on the mainland, (2) N to Woodring Point on Sanibel Island, across 1¾ miles of water to St. James City, then up Pine Island and across Charlotte Harbor to Punta Gorda on the mainland, (3) NE to Bailey's Store on Sanibel Island, across 2¾ miles of water to Punta Rassa on the mainland, then up the Caloosahatchee River, through Ft. Myers, and on to Alva, and (4) E on Sanibel Island to Point Ybel, across 3 miles of water to Fort Myers Beach, then southeast down the mainland coast to Everglades City. Beyond 15 miles the traps were put up where feasible to wire and maintain them. Up to 15 miles an attempt was made to space the traps at mile intervals along each radius, but the discontinuity of land and of wired power made this difficult. Gaps on Sanibel Island and Pine Island were filled with battery-operated traps (S-14, S-15, P-2, P-3).

The 1697 collections yielded 117,185 male and 5,511,958 female *Aedes taeniorhynchus*. The "hot" collections numbered 309 or 18.2 percent of the total. Thirty-six of these hot collections contained 10 or more marked mosquitoes, the largest containing 57. These marked individuals had to be isolated by Geiger counter from unmarked *Aedes taeniorhynchus* averag-

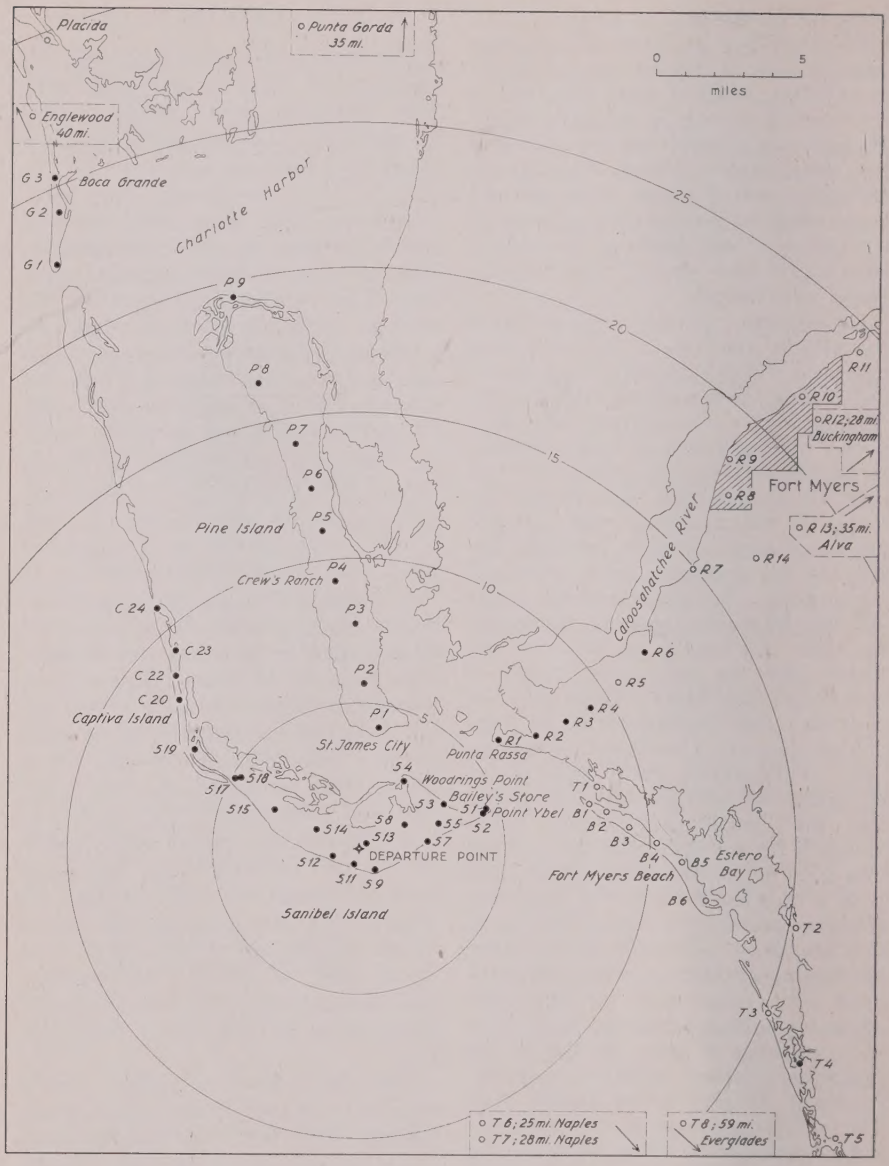

FIG. 1.—Distribution of light traps in second *Aedes taeniorhynchus* dispersal test, Sanibel Island, June 1952. Solid dots are traps which recovered marked females, open circles, traps which did not.

ing 97 males and 9,681 females per hot collection, not to mention the other species. The resulting task of monitoring was far greater than expected. This, in addition to Geiger counter troubles, made it impossible to complete the work before the isotope decayed to background levels; we were left with 110 "hot" light-trap collections with individual marked mosquitoes never isolated. The trend in the 1,132 females recovered indicates that approximately 1,800 marked females were captured by the light traps.

BAIT TRAPS

The bait traps were of a modified Magoon type, 3′ x 6′ with louvers on the two long sides. The goats [1] were of both sexes and moderate to large. Later studies have shown mosquito catches to vary markedly with both size and sex of goats, therefore the collections of marked *Aedes taeniorhynchus* in this experiment must be interpreted cautiously.

Bait traps were used on Sanibel and Captiva Islands only. One was at the departure point. Two were east, 2 and 4½ miles away. Five were to the northwest, 2, 4, and 6 miles away on Sanibel Island, and 8 and 10½ miles away on Captiva Island. The operation of these traps was extremely time-consuming and laborious, and clean collections were hard to obtain.

The eight traps were operated from the day of emergence until July 16, with only 13 collections missed. The entire operation yielded 503,482 female *Aedes taeniorhynchus*. Of the 219 collections, 20 or 9.1 percent were hot. The marked individuals totalled 52.

TRUCK TRAPS

The truck traps were large screen funnels mounted over the cab of pickup trucks and extending to the tail-gate. The opening was 18″ high and 8 feet across, and fashioned like an inverted scoop to gather in not only mosquitoes flying at the level of the funnel opening but also those deflected upward by the front and hood of the truck. At the small end (4″ x 4″) of the funnel, a sleeve of cloth netting was held by an elastic band. The nets were exchanged at flagged points along their routes, making each collection represent a certain stretch of road.

The two truck traps were operated on the main east-west road on Sanibel Island. Starting at a point ¼ mile east of the marking site, one truck went the 4½ miles to Point Ybel and returned, while the other went westward 4½ miles and returned. The routes were divided into portions about 1½ miles long. The total runs were therefore of 18 miles with 14 collections in all. From June 17 to July 12 runs were made starting at 20^h, 23^h, and 04^h; from July 13 to 15 the morning run was eliminated.

The truck trap operation resulted in 1176 collections, of which 77 or 6.6 percent were hot. In all, 82,287 male and 344,148 female *Aedes taeniorhynchus* were collected, of which number 7 males and 89 females were marked.

ROTATING-NET TRAP

A "rotor" trap was operated at the departure point. The nets were a yard square and rotated 17¼ times per minute at the end of 10-foot arms (to center of net). The nets therefore advanced at approximately 12½ miles per hour and each of the two nets sampled approximately 9,600 cubic feet of air per minute.

The trap was operated from June 18 to July 16, with one night of failure. Of its 28 collections, 10 were hot. The nightly collections totalled 5,418 male and 48,665 female *Aedes taeniorhynchus*. On the night of departure 151 male and 119 female marked ones were caught. The remainder of the operation yielded 2 male and 30 female marked mosquitoes (Table 3).

[1] These animals were kindly lent us by the (then) U.S.D.A. Bureau of Entomloogy and Plant Quarantine screw-worm eradication research program, at that time on Sanibel Island.

E. THE DEPARTURE

From previously acquired knowledge we knew that the departure on a migratory flight would occur at night only, and only when the new adults were over 6 to 8 hours old (Nielsen, in press). When the big emergence came on June 17 in late afternoon, it was surmised that the departure would be mostly after midnight.

A canvas had been spread over the larval vats for shade. As the emergence progressed in the afternoon, the new mosquitoes expanded their occupation of available resting surfaces. In time the inside and outside of the vats, together with the sawhorses that kept them off the ground, were solid resting mosquitoes. Then the advancing numbers spread to the grass in the shade, then up the canvas ropes, and finally all over the underside of the canvas. By sunset, the outside of the canvas was well-covered, with many crowded along the "ridgepole" of the tent-like canvas while the mosquito mass had spilled out to occupy the grass within several feet of the tent. Some of the mosquitoes reached out to within a few feet of the rotating net trap which had been set up about 40 feet from the tent. After sunset some of the mosquitoes left permanently when disturbed but most resettled and remained. At several of the poles holding the tent and at the gable ends, wisps of mosquitoes took off spontaneously in "puffs" much as Nielsen had noticed in earlier studies (Nielsen, in press). The overwhelming majority stayed behind, however, and two hours after sunset there appeared to be virtually as many mosquitoes as at sunset. Between midnight and 03^h there was a gradual departure. Well before dawn, the great mass of new mosquitoes had gone.

All the recovery methods were in operation on the night of departure (Table 1). Recaptures away from the departure point were too few to mean anything but that whatever flight was under way was not being adequately sampled. The light trap at the point of departure caught 35 marked mosquitoes. This is an excellent demonstration of the fact that newly-emerged mosquitoes and those taking off on their first dispersal flight are simply not attracted to light. Thirty-five caught when a million and a half were within 100 feet of the trap during a good deal of the night certainly indicates no light attraction. The 35 caught were accidentally

TABLE 1.—Recoveries of marked *Aedes taeniorhynchus* during night of departure, June 17–18, 1952, on Sanibel Island

	Light Trap			Rotating Net Trap		
	Time	♂	♀	Time	♂	♀
At departure point (DpP)	Sunset–21^h	5	6	18^h–20^h	128	42
	21^h–22^h			20 –22	30	40
	22 –23		1	22 –23	4	3
	23 –24	5	5	23 –24	5	12
	00 –01		2	00 –01	3	7
	01 –02		2	01 –02	6	19
	02 –03	2	2	02 –03	2	16
	03 –04	3		03 –04		1
	04 –05		1	04 –05	2	6
	05 –06		1	05 –06	1	13
	Total	15	20	Total	181	159

Light trap S–9 ¾ mile southeast of DpP.	1 ♀ sometime during night.	
Truck trap, along E-W road ½ mile north of DpP.	c. $23^h30'$	1 male
	c. $04^h15'$	1 female
	c. $04^h45'$	1 male

sucked in as they flew through the trap. The rotating net trap also caught extremely small numbers, very likely because the angle of take-off for most of the mosquitoes carried them clear over the nets, which were only three feet above the ground some 40 feet from the tanks. Those caught before sunset (18^h–20^h) were undoubtedly disturbed mosquitoes which had flown within the orbit of the trap.

F. THE MIGRATORY FLIGHT

If the migration occurs on the night of departure, the data in Table 1 indicate a very poor sampling of actual migrants. If migration occurs also on the second night, again it appears that actual migrants were inadequately sampled. Disregarding collections at the point of departure, we find the following array of total marked females recovered per night in the different samplings:

Night from departure:	Dp	2	3	4	5	6
Truck traps	1	9	*23*	13	6	8
Goat-bait traps	0	1	7	*17*	9	7
Light traps	1	20	201	235	*317*	151

A study of this series is enlightening, remembering always the possible influence of weather conditions.

Light traps sample only that portion of the population which is at the time positively phototactic. It is still not known under what physiological conditions female *A. taeniorhynchus* are attracted to light. The 1951 experiment (q.v.) demonstrated a peak of light-trap attraction every five days, starting on the fourth. In this experiment the first peak was on the fifth night and subsequent peaks were not established. It is clear, however, that light traps recovered very few marked females on the night of departure and the next night, in both experiments. If these are the migration nights, we must conclude that light traps do not adequately sample the migrants, however efficient they may later be in sampling the brood after it has "settled down."

Traps baited with goats also attract a certain segment of a brood only, viz., the ones searching for blood at that time. In this experiment the first peak of attraction was on the fourth night, substantiating the finding of Nielsen and Nielsen (1953) that biting is most severe the fourth night after emergence. From the figures given above, it is obvious that bait traps do not sample migrant females any better than light traps.

It would appear at first thought that truck traps sample the migrants since they are air samplers and not attractant samplers. It is seen, however, that the greatest catch was on the third night, the second night recovering only 1/3 as much and the first night 1/20. If truck traps were non-selective their catches would reflect generally the population curve as it decreased with age and the first and second nights would normally exceed the third and fourth nights. The record, on the contrary, indicated very poor sampling of the population on the first two nights. This is indirect evidence that the migratory flight was either or both (1) at levels well above the height of the truck traps, and (2) in channels or streams which could only by rare chance be intercepted by trucks.

The conclusion, then, is that the actual migration was not sampled in this experiment and that all the collecting methods employed sampled the marked population only after the migratory interval, when it had settled down and was dispersing by appetential flight only.

G. THE ULTIMATE DISPERSAL OF FEMALES

The weather on the night of departure was that of a typical summer day in the area. According to the U. S. Weather Bureau the conditions at Ft. Myers were as follows. Temperatures dropped from 78.6° F. at 18^h to 73.0° at 05^h in the morning. The relative humidity remained above 90 percent all night. Cloud cover was complete at 18^h but disappeared totally by 21^h; there was no precipitation. The winds were from east

TABLE 2.—Recoveries of marked *Aedes taeniorhynchus* females in light traps after departure (Dp) on Sanibel Island, June 17–18, 1952. DpP is departure point. x are radioactive collections not monitored down to individual mosquitoes.

	Nights from Exodus Light Trap	Miles	Dp	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
<1 mile	DpP	0	20	2	2	1	2	3	3	1	–	x	–	–	x	x	–	x	x	–	–	–	–	–	–	–
	S – 13	¼		3	19	25	36	15	5	2	3	x	x	x	x	x	x	x	x	x	x	–	–	–	–	–
	S – 9	¾	1	2	6	12	11	2	4	7	8	x	–	–	x	–	–	–	x	–	–	–	–	–	–	–
	S – 11	¾		1	17	1	–	1	4	4	1	x	x	x	x	–	x	x	–	x	–	–	–	–	–	–
	S – 12	1			3	1	1	–	2	2	–	–	–	–	–	x	–	–	x	–	–	–	–	–	–	–
NW—Outer Islands	S – 14	1¾			10	7	7	4	3	7	4	x	–	x	–	–	–	–	–	x	–	–	–	–	–	–
	S – 15	3¼			1	4	4	4	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–	–	–
	S – 17	5			–	2	4	3	1	1	–	x	–	x	–	–	–	–	x	–	–	–	–	–	–	–
	S – 18	5			–	1	2	2	2	x	4	x	–	–	–	–	x	–	–	–	–	–	–	–	–	–
	S – 19	7			11	24	33	10	1	3	1	x	x	x	x	–	–	x	–	x	–	–	–	–	–	1
	C – 20	8			1	6	2	6	1	2	2	x	x	x	–	–	–	–	–	–	–	–	–	–	–	–
	C – 22	9			2	1	15	7	2	4	1	x	x	–	–	–	–	–	–	–	–	–	x	–	–	–
	C – 23	9½			1	2	–	6	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	C – 24	11			3	4	3	6	4	4	2	x	x	–	–	x	–	x	–	–	x	–	–	1	–	–
	G – 1	22½			–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	G – 2	24			–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	G – 3	25			–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Placida	30			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Englewood	40			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N—Pine Island	S – 4	2¾			28	26	57	4	5	10	6	x	x	x	x	x	x	–	–	–	–	–	–	–	–	–
	P – 1	4½			1	1	–	–	1	2	2	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	P – 2	5¾			–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	P – 3	7½			–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	P – 4	9½			4	4	9	11	x	–	x	x	–	x	–	–	–	–	–	–	–	–	–	–	–	–
	P – 5	11			2	6	2	5	1	–	x	x	x	–	–	x	–	–	–	–	–	–	–	–	–	–
	P – 6	12½			–	2	4	2	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	P – 7	14½			1	2	5	4	3	1	x	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	P – 8	16½			–	6	–	3	2	–	x	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	P – 9	19½			–	1	1	4	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Punta Gorda	35			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

| | | |

and south, particularly east, throughout the night; velocities were generally 3 to 7 miles per hour. Sunset was at $19^h24'$ and sunrise at $05^h36'$.

On Sanibel Island, at the point of departure, an accurate record of wind conditions was kept. The resulting picture (Fig. 2) differs in minor details only from what was indicated at Ft. Myers, 20 aged 4½ miles per hour. The general similarity of wind conditions between the two experiments at the point and time of departure makes it feasible to discuss differences in dispersal on the basis of variables other than weather.

LIGHT-TRAP RECOVERIES (Table 2)

Because light traps attract the females of *Aedes taeniorhynchus* mostly when they

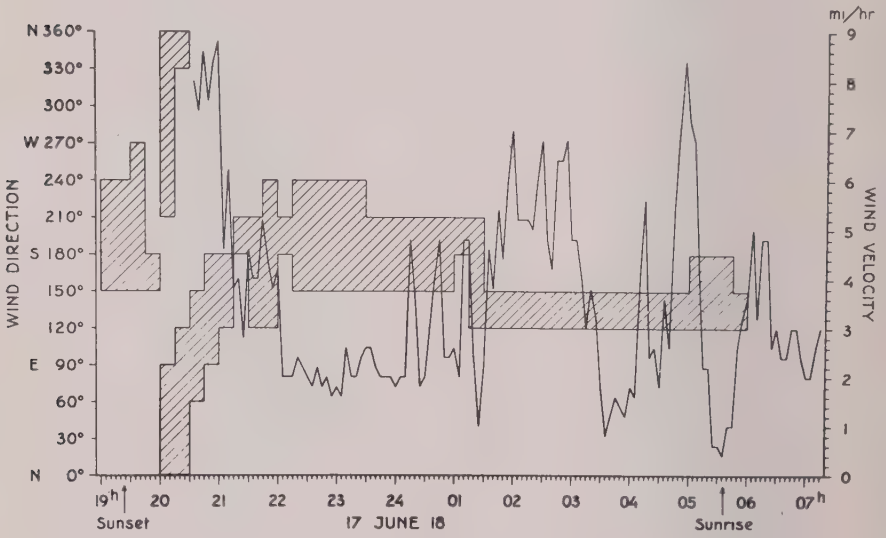

FIG. 2.—Wind conditions at departure point on night of departure. The mosquitoes left mostly between midnight and 03^h.

miles away. During most of the departure, the wind was from the southeast, averaging 4 miles per hour. On the three nights following the departure, wind directions and velocities were determined on a synchronized basis during the early part of the night and before dawn, at the marking point, at Point Ybel, and at Woodring's Point. There were so many cases of opposite winds at these points within a two-mile radius, and so little overall agreement in either direction or speed of wind, that we cannot assume that wind measurements taken at one point prevailed over any sizeable geographical area.

During the release of the 1951 experiment the wind was from the east and aver-

are four or five days old, it is not possible to learn any details of the actual migratory flight from their recaptures. A mosquito caught at a light trap ten miles away on the fifth night could have reached that locality on the first night within a few hours of departure. Or the migratory flight could have brought it only half the distance, the remainder having been spanned by any number of appetential flights (Provost, 1953). Marked *Psorophora ferox, Haemagogus spegazzinii,* and *Aedes serratus* released at advanced ages when the likelihood of further migration was extremely slight have nevertheless flown over 10 kilometers (Causey *et al.,* 1950) in what were almost surely

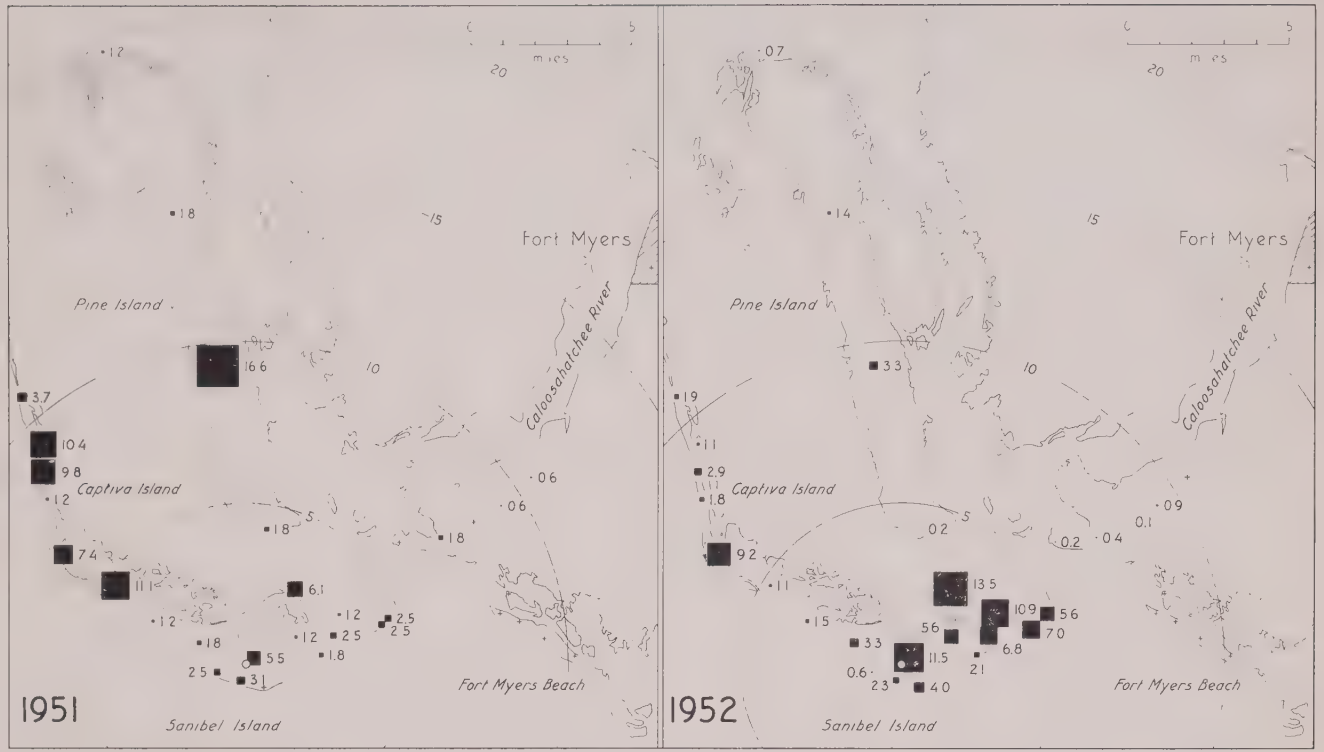

FIG. 3.—Comparison of 1951 and 1952 dispersals of female *Aedes taeniorhynchus* based on traps operated in both experiments and recoveries for first six nights. Figures are per cent of total recovery for experiment and size of square is proportional thereto. Crosses are negative traps.

appetential flights. We must remember, then, that a light-trap recovery in itself gives us no information on when or how the mosquito reached that particular point.

The ultimate area of occupancy by the marked brood on the basis of females recovered in light traps is given in Fig. 1 and is seen to be very much like that obtained in the 1951 experiment (q.v.). In order to compare the two experiments better, only those traps which were used both years and the results of the first six nights only, are plotted in Fig. 3. In both experiments the distant dispersal was primarily downwind, i.e. north and west on the outer islands and on Pine Island. The Pine Island route involved a 1¾ mile flight over water, at minimum. The seeming "pile-up" at Woodring's Point (S-4), in both experiments, suggests that many may have been deterred from an over-water flight of some two miles, even when downwind. Nevertheless substantial numbers crossed over to Pine Island; in the 1951 experiment no less than 16.6 percent of all females recovered by light trap in the first six nights were caught at Crew's Ranch near the middle of Pine Island. The apparent accumulation at Woodring's Point was therefore more likely the result of appetential flight concentration about a good resting and breeding area.

In both experiments there also seemed to be a piling up at Point Ybel, 4½ miles east of the point of departure, with exceedingly few mosquitoes crossing the 2¾ miles of water northeasterly to the mainland. The few which did cross, to appear at points up the road toward Ft. Myers, could easily have gone across on the ferry. This is very likely since passenger cars line up at the Sanibel ferry-landing several times a day at a spot notoriously mosquito-ridden.

None of the marked mosquitoes flew eastward or southeastward to Ft. Myers Beach, 3 miles over water, and on down the mainland coast. The lone female from the second experiment captured at the southern end of Estero Bay (T-4) 21 days after emergence probably reached that point by passive transport, because any flight to that distant (16½ miles) point would certainly have yielded many recaptures the first few nights after departure, not only there but at the many traps in that direction at lesser distances. The outstanding conclusion from these two experiments is, therefore, that *Aedes taeniorhynchus* do not undertake long flights over water against the wind.

The most pronounced difference between the two experiments is that in 1951 50 percent of the females left Sanibel Island while in 1952 only 16 percent did so. This is explainable most easily on the assumption that migratory flights occur only on the night of departure. In 1951 the departure was at twilight and the mosquitoes presumably had all night to migrate; half of them flew to Captiva and Pine Islands. In 1952 some of the earlier ones to take off were presumably able to do the same thing and thus account for the 8 percent recovered on Captiva and the 6 percent on Pine Island, but the great majority did not take off until after midnight and were apparently still on Sanibel Island at dawn and so 84 percent of marked mosquitoes were eventually recaptured on the island. If this explanation is correct, another conclusion is implied, viz. that appetential flights are not undertaken over any wide expanses of water. The true explanation of these dispersals will, of course, have to await a better understanding of both migratory and appetential flights.

Interpreting the dispersal as the result of a migration only, with dispersal by appetential flights inconsequential, would force the conclusion that large numbers migrated upwind or quartering the wind, especially in the 1952 experiment. If, contrariwise, we assume that appetential flights may span miles of terrain, it becomes possible that all the marked mosquitoes went downwind and that the occupation of the eastern half of Sanibel Island was the result of post-migration movements. These latter movements would tend to concentrate the mosquitoes where

TABLE 3. Recoveries of marked *Aedes taeniorhynchus* females in truck traps, in traps baited with goats, and rotating net trap (at departure point), on Sanibel and Captiva Islands

Nights from Departure (Dp)			Dp	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Truck Traps		Within ½ mile	1	4	3	1	1	2	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		East ½ mile +		2	6	4	2	4	2	1	–	–	–	–	–	1	–	1	–	1	–	–	–	–	–	–
		West ½ mile +		3	14	8	3	2	6	3	3	–	2	1	–	1	1	–	1	–	–	–	–	–	–	1
		Within ½ mile	1	4	3	1	1	2	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		½–1½ miles		2	6	5	3	1	3	2	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1
		1½–3 miles		2	9	4	1	2	2	–	1	–	1	1	–	1	1	1	–	1	–	–	–	–	–	–
		3 –4½ miles		1	5	3	1	3	3	2	1	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–
		Total	1	9	23	13	6	8	8	8	3	–	2	1	–	2	1	1	1	1	–	–	–	–	–	1
Goat Traps		Departure Point			5	4	4	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
	East	2 miles			–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	East	4½ miles		1	2	10	–	6	–	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–
	Northwest	2 miles			–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Northwest	4 miles			–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Northwest	6 miles			–	–	2	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–
	Northwest	8 miles			–	–	3	–	–	–	–	1	–	–	–	–	–	–	–	–	–	2	–	–	–	–
	Northwest	10½ miles			–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Northwest	Total		1	7	17	9	7	3	–	–	1	–	–	3	–	–	–	–	1	–	3	–	–	–	–
Rotating Net Trap			159	7	3	5	5	5	2	–	–	–	–	1	1	1	–	–	–	–	–	–	–	–	–	–

TABLE 4.—Recoveries of marked *Aedes taeniorhynchus* males after departure June 17–18, 1952 on Sanibel Island

Nights from Exodus		Dp	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Light Traps	Departure Point	15		1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	S – 13 (¼ mile NNE)		1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	S – 9 (¾ mile SW)			–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	S – 11 (¾ mile S)			1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Truck Traps	Departure Point (—½ m.)	2	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	½ – 1½ miles W			–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	1½ – 3 miles E			–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–

resting and breeding areas are superior and close to one another—exactly the situation at such light traps as S-1, S-3, S-4, and S-19.

GOAT-TRAP RECOVERIES (Table 3)

The ultimate dispersal of the marked brood cannot be very well assessed from the bait-trap recoveries of this experiment. There were encouraging signs, however, for later usefulness of a better-designed baiting program. The recoveries did give some intimation of the first biting cycle, as mentioned earlier, and recoveries as late as the 20th night give some indication of biting at advanced ages. There is no obvious explanation for the strange fact that goat-trap collections were high on precisely the nights when truck-trap collections were low. This was particularly noticeable after the first gonotrophic cycle.

TRUCK-TRAP RECOVERIES (Table 3)

Marked females were caught by truck trap up to the 24th night from departure. The trucks operated up to 4½ miles east and west of the departure point, and within these limits there seemed to be no correlation of numbers with distance. The recoveries to the west, however, were twice as numerous as those to the east, a result difficult to interpret without more detailed information on where the brood settled down. The truck traps have a great potential for establishing the eventual dispersal of a brood, but they need further study as a technique.

H. THE DISPERSAL OF MALES

The dispersal of male *Aedes taeniorhynchus* as revealed in this experiment (Table 4) was a repetition of the 1951 findings (q.v.). The questions raised by the latter still remain unanswered. Sampling of twilight swarms was attempted, with negative results. Such collecting may be the only way to determine the ultimate dispersal of males, but it would have to be done on a far greater scale than was attempted in this experiment.

I. SUMMARY

1. A new technique for the production of *Aedes taeniorhynchus* in the field under controlled conditions is described.

2. A million and a half radioactive mosquitoes were allowed to disperse freely from the middle of Sanibel Island, the main departure occurring in the middle of the night.

3. Recoveries were by means of light traps, goat-baited traps, and air-sampling traps mounted on trucks.

4. Females were recovered up to 25 miles away and until the 24th night after emergence.

5. Only a few males were recovered, all within three miles.

6. The dispersal was generally downwind.

7. Findings support the following hypotheses:

a. Migration occurs the night of departure only, therefore twilight departures will result in longer migrations than middle-of-the-night departures.

b. Appetential flights expand the range of occupation by a brood much beyond what is established by the migration.

c. Appetential flights are not undertaken across any sizable expanse of water.

J. ACKNOWLEDGMENTS

The encouragement and assistance rendered the author by Mr. John A. Mulrennan, Director of the Bureau of Entomology, Florida State Board of Health, is gratefully acknowledged, along with the splendid work in the field by a very large number of the Bureau's personnel. The valuable help and counsel of my colleague, Dr. Erik Tetens Nielsen and his late wife, Astrid Tetens Nielsen, are remembered with appreciation and pleasure.

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HIGHLAND VALLEY FARM—Walhonding, Ohio

SYNTHESIS OF AMINO ACIDS IN *AEDES AEGYPTI* L.[1]

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INTRODUCTION. Insect nutrition has received increasing attention in recent years (Trager, 1953; Lipke and Fraenkel, 1956). At the present time, the specific nutrient requirements are known for a number of insects (Albritton, 1954). Mosquitoes have been particularly interesting subjects for nutritional studies, since the larval and adult stages require different nutrients, and have entirely different feeding habits.

An aseptic method of rearing mosquitoes on a completely chemically-defined diet has permitted further advances in the study of amino acids in mosquito nutrition (Singh and Brown, 1957). Also, techniques such as paper chromatography have provided information concerning the free amino acids which naturally occur in mosquitoes (Micks and Ellis, 1951, 1952; Micks, 1956). Little is known, however, regarding the extent to which mosquitoes are capable of synthesizing the non-essential amino acids. It was of interest therefore to combine the two above-mentioned methods to obtain new information concerning this point. The results of this work are presented herein.

MATERIALS AND METHODS. *Aedes aegypti* larvae were raised aseptically on a chemical diet employed by Singh and Brown (1957). The amino acid mixture used in this diet was composed of glycine, alanine, valine, leucine, isoleucine, proline, hydroxyproline, phenylalanine, serine, tyrosine, histidine, arginine, tryptophane, threonine, methionine, cystine and lysine (Table 1). Each of the amino acids (alanine, glycine, serine, tyrosine, systine and proline) which had been found non-essential for *A. aegypti* larvae (Singh and Brown, 1957) was omitted singly from the diet. Two-dimensional chromatograms of fourth-stage larvae from this strain were compared with chromatograms of the regular laboratory-reared strain of *A. aegypti* to determine if those amino acids omitted from the diet were present on the chromatograms. Since the Rf values of all the non-essential amino acids had been previously determined from chromatograms of the regular strain, the appearance of any one of these when omitted from the chemical diet constituted evidence of synthesis.

Fourth-stage larvae were collected and placed in boiling distilled water for two minutes to coagulate the protein. The excess water was removed by touching the specimens to a piece of blotting paper. The larvae were mashed on chromatographic paper with a glass rod with a flattened end. A stream of hot air was

TABLE 1.—Composition of the mixture of amino acids employed in the chemically defined diet.

Amino Acid	Concentration g/1
Glycine	0.25
L-Alanine	1.00
L-Valine	1.20
L-Leucine	1.00
L-Isoleucine	1.12
L-Proline	0.75
L-Hydroxyproline	0.18
L-Phenylalanine	1.00
L-Serine	1.40
L-Tyrosine	0.50
L-Histidine (mono HCl)	0.25
L-Arginine (mono HCl)	0.39
L-Tryptophane	0.36
L-Threonine	0.75
L-Methionine	0.70
L-Cystine	0.13
L-Lysine (mono HCl)	0.66
Total	11.64

[1] This investigation was supported (in part) by a research grant No. E98 (C5) from the National Institute of Allergy and Infectious Diseases, Public Health Service.

[2] James W. McLaughlin Postdoctoral Research Fellow.

used to dry the paper following the application of each specimen. Ten larvae were used for a single chromatogram. Two-dimensional chromatograms were prepared using Whatman No. 3 mm filter paper cut into 11" x 11" sheets. Cellophane tape was used to fasten the chromatograms into cylinders. Propanol-diethylamine-water (85:4:15) was used as a first solvent and butanol-acetic acid water (4:1:1) was employed as the second solvent. Developed chromatograms were dried by hanging them in a cabinet equipped with a small exhaust fan. They were then sprayed with 0.2 percent ninhydrin in water-saturated butanol using a nasal atomizer and dried again.

Colored spots representing free amino acids were cut from chromatograms of both strains of *A. aegypti*. These were then run through a Photovolt transmission densitometer for the purpose of obtaining density curves. The comparative densities of seventeen amino acids in the two strains were then calculated with a planimeter, and the values expressed as area in square centimeters.

Fig. 1.—Two-dimensional chromatogram of *Aedes aegypti* fourth-stage larvae (diet strain). Propanol-diethylamine-water was used as the first solvent and butanol-acetic acid-water as the second. The numbered spots represent the following amino acids: 1, cystine; 2, arginine and aspartic acid; 3, glutamic acid; 4, lysine; 5, glutamine; 6, glycine; 7, serine; 8, histidine; 9, threonine; 10, alanine; 11, proline (not visible because of yellow color); 12, tyrosine; 13, methionine and valine; 14, leucine and isoleucine; 15, taurine (not visible); and 16, β-alanine (not visible).

Results. Each of the non-essential amino acids, omitted singly from the amino acid mixture of the diet strain appeared on the chromatograms of the fourth stage larvae. Furthermore, aspartic acid, glutamic acid, β-alanine, taurine and glutamine, which were not included in the diet of this strain, were also present on the chromatograms (Figure 1). A comparison of chromatograms of the two strains also revealed striking differences in concentrations of certain amino acids (Table 2). The laboratory strain contained significantly larger amounts of several of the non-essential amino acids. The concentration of tyrosine, for example, was approximately twelve times higher in this strain, which also possessed about twice as much cystine, lysine, histidine, arginine + aspartic acid, glutamic

TABLE 2.—A quantitative comparison of free amino acids in fourth-stage larvae of two strains of *A. aegypti* [1]

Amino Acid	CD Strain [2]	Laboratory Strain
Proline	0.7	1.4
Alanine	6.4	11.2
Threonine	4.8	4.4
Glutamine	5.6	7.0
Isoleucine + Leucine [3]	2.6	2.9
Methionine + Valine [3]	2.6	3.0
Tyrosine	2.4	23.1
Cystine	7.5	15.0
Lysine	2.4	5.7
Histidine	5.3	10.8
Arginine + Aspartic acid [3]	7.4	16.8
Glutamic acid	4.2	9.1
Glycine	4.2	5.7
Serine	4.4	2.8

[1] Values given refer to area in cm^2.

[2] Aseptically reared on a chemically-defined diet.

[3] Amino acids represented by a combined value since the spots were not completely separated on the chromatograms.

acid, proline and alanine as the diet strain. On the other hand, the essential amino acids were present in comparable amounts in the two strains.

DISCUSSION. It is obvious from the results that *A. aegypti* fourth-stage larvae are able to synthesize most, if not all, of the non-essential amino acids. Their presence in larvae reared aseptically on the special chemical diet indicates that they are produced by some mechanism such as transamination or deamination during amino acid metabolism.

It is of particular interest that glutamic acid was not included in the special diet and yet appeared on all chromatograms. There is evidence from other insects that glutamic acid may be a product of transamination. Kilby and Neville (1956) and Barron and Tahmisian (1948) have demonstrated the formation of glutamic acid by transaminases in locust and cockroach (*Periplaneta americana*) tissues respectively. The presence of glutamate/alanine was reported by these investigators in both insects and Kilby and Neville also demonstrated glutamate/aspartate in the locust. It seems likely that mosquitoes may also synthesize alanine, aspartic acid and glutamic acid by means of such transaminases.

Other evidence of amino acid synthesis has been provided by Auclair (1949), working with cockroaches. He found that ingested alanine caused an increase in glutamine and glutamic acid, while an increase in glutamine, alanine and α-ketoglutaric acid raised the glutamic acid content. He also observed that asparagine fed to the insects increased the amounts of aspartic acid and glutamine in the hemolymph.

It can be seen from the results that although *A. aegypti* larvae are able to synthesize serine and glycine, they are not capable of synthesizing sufficient proline since they do not grow well on a proline-deficient diet. Likewise, cystine can be synthesized but not in sufficient quantity, because when it is omitted from the diet development continues only as far as the fourth instar and pupation does not occur. Tyrosine, although not required by *A. aegypti* larvae in the diet, evidently is converted from phenylalanine.

It is interesting that most of the non-essential amino acids are present in larger amounts in the laboratory strain. This difference between the two strains may also be reflected in the length of the life cycle which in the regular laboratory strain is approximately ten days, as compared with eighteen days in the diet strain. These findings suggest that the larvae grown on the chemical diet under aseptic conditions may not receive optimal quantities of these amino acids.

SUMMARY. *Aedes aegypti* larvae were reared on a completely chemically-defined diet under aseptic conditions. Non-essential amino acids (alanine, glycine, serine, tyrosine, cystine and proline) when omitted individually from the diet were present on two-dimensional chromatograms of larvae of this strain, indicating amino acid synthesis.

A quantitative chromatographic comparison of the chemical diet strain with the regular laboratory strain revealed marked differences between the two as to concentrations of certain amino acids, particularly the non-essential ones.

ACKNOWLEDGMENT. The authors express their sincere thanks to Dr. Andrew A. Ormsby for calculating the values given in Table 2.

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I hope my remarks on this subject will reflect the vital interest that our industry has in your problems and your programs. We want to help solve the problems and promote your programs in every way that we can.

The most obvious way that we can assist is by providing insecticides that are safe, effective and economical. I think you will agree that we are providing you with such insecticides today in spite of the resistance factor.

An insight into how economical insecticides have become is given by some figures I have here. They come from an analysis our industry did on the monies expended by various mosquito abatement districts. These figures tell us that in no instance did the purchase of insecticides account for as much as 10 percent of the total funds spent by the district reporting and, as a matter of fact, in many instances the purchase of insecticides accounted for less than 5 percent of total funds expended!

A second way our industry can assist you is in its continuing research projects. Even though we supply you today with effective and economical insecticides our scientists still search for products that will do an even more effective and more economical job of insect control, and will, we hope, continue to cope with resistant forms.

It may appear to some of you that our research efforts are directed almost exclusively to agricultural problems. Certainly, it is true that the greatest amount of our research work lies in this area. And for good reason. To our industry the mosquito problem in this country appears small when compared to the problems created by pests plaguing the farmer and his crops. Today, malaria has been all but wiped out of our country. This fact is a tribute to the fine work that you people have done. It also shows that you have had the insecticidal weapons with which to do your job. So, from the standpoint of comparative need alone, it is obvious why the brunt of our research effort is directed toward agricultural problems.

In the view of an outsider, it appears that our industry has been able to assist your work most successfully where community effort has been organized toward the elimination of disease-bearing and pest mosquitoes. This kind of effort is usually backed by all or most of the funds which would otherwise be spent by individuals in the community to kill mosquitoes. I think you will all agree that when such funds are pooled on a community or locality basis, you are able to bring about more effective control. The problem then seems to be: how to bring

about such community-wide effort in more communities.

I am not proposing that private industry take the lead in organizing such efforts. I do not think it is properly our domain. Our role should only be one of cooperation.

It is our belief that inspiration for the organization of abatement districts (usually arising locally from service clubs) should continue to be encouraged by state authorities and that technical and financial assistance should be given where major problems exist. In this connection, I believe that the companies in our industry would gladly give their fullest support to such programs.

The foreign aid health program, although different in scope, will give you an example of the course that our industry's cooperation could take. In effect, we have helped tailor-make an insecticidal program to a given country. At the start of such a program, specialists were sent into remote areas of the world to study the requirements of the particular locality. Coordinating meetings with representatives of our industry were held by authorities of the World Health Organization, the Pan-American Sanitary Bureau, the U. S. Department of Agriculture, the U. S. Public Health Service and members of the Armed Services. Then special formulations of insecticides were developed . . . special packaging was designed . . . concentrated formulations prepared. Double air-grinding was found necessary in some cases, and specialized blends of surface active agents were worked out to give the desired performance in waters with high alkalinity, in spite of extended storage under tropical conditions.

The packaging problem alone was quite a task. The insecticide had to travel on almost every conceivable type of transportation from ship and airplane to camel and mule trains and be subjected to the most rigorous type of handling and storage.

Not all important problems relating to mosquito control have been solved. Aside from the development of resistance, one of the most important which has come to light during the past few years has been the deactivation of insecticidal residues on certain sorptive mud surfaces.

Our industry has already invested heavily in research to solve this problem. When we have solved this problem we believe that we will have advanced pest control technology in agriculture, in livestock pest control, as well as in the eradication of malaria, filariasis and other diseases.

We further believe that the many contributions that have been made by our industry to the technology of pest control and specifically to the control of disease vectors is generally recognized and apparent to those investigators working in the field of mosquito control in this country. Many of your own members have served one or more tours of duty working in remote areas and they are most assuredly in a position to apply the benefits of such experience to the advantage of our domestic pest elimination problems. It is possible that there could be better dissemination of such knowledge to those engaged in mosquito abatement in this country. However, it is my firm belief that the chief need of mosquito control effort in the United States is not so much one of technology as it is a need for education, organization and appropriation.

Organization-wise, perhaps mosquito control will have to be affiliated with other forms of pest abatement, particularly in those areas where the mosquito problem is not acute nor constant. Where there are other problems such as tabanids, eye gnats, midges, or even unrelated community-wide pest problems such as weeds, grasshoppers, gypsy moths, control might best be carried out on a community-wide basis by organized effort. In such communities I feel our industry can make a more worthwhile contribution to your cause where community-wide pest control, such as the control of disease vectors and nuisance pests, is coordinated in a single community-wide program. Under such a pro-

gram you could not only gain more efficient control of mosquitoes, but perhaps for very little additional funds, could also gain control over agricultural and other pests common to the area, by using the same equipment, the same personnel, the same administration—in some instances the same insecticide and the same application. I suggest such a program as a possible solution only for those communities where mosquitoes are not sufficiently troublesome to require an orthodox mosquito abatement district.

Two strong selling points for such a program are added efficiency and added economy. Companies in our industry could help bring about these benefits by developing ways to supply multiple purpose formulations which would simultaneously strike at noxious weeds, grasshoppers and mosquitoes in a single application.

There are in almost every area many representatives of our industry who are highly trained in the science of insect eradication or control. Most of these men could help plan such a community-wide program. The insecticide industry can also supply you with literature to help educate residents of a community to the need for organized pest control. We can also make films available to you to help supplement such an educational campaign. Two such films are Sinclair Oil Company's "Five-Hundred-Thousand to One" and a film produced by my own organization titled "The Rival World." I think you will find that both films are excellent examples of education by drama.

Looking back over the points that I have tried to make this morning, it appears that the insecticide industry can help you both in your job of controlling mosquitoes and other insects and in your job of selling your community on the need for such control. In the first instance, our assistance shows up in our role as a supplier of materials for insect control . . . and in our research efforts the aim of which is to supply you with more effective and cheaper insecticides.

The organization of control programs is rightly the responsibility of you people and other residents of your individual communities. Representatives of our industry who are members of a given community can help you plan the most effective type of control, and I'm sure you will find that the majority of them will be glad to do so. And our industry, as a unit, can assist you in your job of educating a community to the need for control.

This is the assistance our industry can offer. To it I will add my personal compliments for the health and life-saving job you have done by your work in controlling mosquitoes in this country . . . and my best wishes for continuing success.

DESPLAINES VALLEY MOSQUITO ABATEMENT DISTRICT

8130 Ogden Avenue, Lyons, Illinois

Member of American Mosquito Control Association

Trustees

Otto McFeely, President; Charles F. Scheel, Vice-President; John J. Callahan, Secretary; Francis P. Creadon, Treasurer; William E. Goersmeyer, Ass't Secretary.

Franklin C. Wray, Technical Director

The District was created under state law adopted in 1927 by the General Assembly of Illinois. The District has functioned for twenty-nine years.

THE USE OF INSECTICIDES AGAINST ADULT MOSQUITOES [1]

KENNETH D. QUARTERMAN

There are two general methods in which insecticides are used against adult mosquitoes—by application of insecticidal residues on surfaces on which adult mosquitoes rest, and by direct application of insecticides to the insects by means of space sprays, mists, aerosols, or dusts.

Of the total tonnage of insecticides used in mosquito control on a global basis, a very high percentage is applied as residual sprays to control adult mosquitoes, aimed primarily at the control or eradication of malaria. DDT is the most commonly used insecticide for this purpose, followed by dieldrin and benzene hexachloride.

DDT is applied in most areas at a dosage rate of 200 mg. per sq. ft., although dosages ranging from 25 mg. to 260 mg. per sq. ft. have been used in some countries (Pal and Sharma, 1955) (Macdonald and Davidson, 1953). Water-wettable powders containing 75 percent DDT are generally the formulation of choice for residual house spraying with this insecticide. In some of the better homes where wettable powders may leave unsightly residues, water emulsions or kerosene solutions are employed. The finished spray is applied usually at the rate of 4 ml. per sq. ft. and the concentration is varied to give the desired dosage. Five percent suspensions, emulsions, or solutions give deposits of 200 mg. per sq. ft. and are the concentrations most commonly used. The frequency of applications ranges from 6 weeks with the lower dosages to once or twice annually with the higher ones, depending on a variety of such factors as vector species, climate, and type of construction treated.

Dieldrin is applied generally at dosage rates of 25 mg. or 50 mg. per sq. ft., using 0.625 or 1.25 percent suspensions prepared from 50 percent wettable powders. Frequency of application varies, but is usually once or twice annually.

BHC is applied at dosage rates ranging from approximately 10 mg. to 50 mg. of gamma isomer per sq. ft., with the greatest usage in the 20–25 mg. per sq. ft. range. Wettable powder formulations are used predominantly and frequency of application ranges from 6 weeks to 6 months.

Since the use of residual sprays for the control of malaria began, great improvements have been made in hand spraying equipment and insecticidal formulations. Present-day hand sprayers are specifically designed for sustained usage in house spraying under rugged field conditions and are a far cry from the flimsy units which were the only type of such equipment available in pre-DDT days. The constant strengthening and development of standardized sprayer specifications (WHO, 1956[a]) and testing techniques (Hall, 1955) for use by United States and international procurement agencies have been important factors in bringing about the improved sprayers.

Similarly, in the early days of house spraying for malaria control, serious difficulties were encountered with the water-wettable formulations of DDT purchased for use in overseas areas. These difficulties were due primarily to inadequate specifications. Again, research and development by United States and international agencies and industry have resulted in the development of standardized specifications (WHO, 1956[b]) (Pearce, *et al.*, ms.) for wettable powders which will give satisfactory performance in tropical areas if the specifications are adhered to properly during manufacture.

The two principal problems being encountered today on vector control programs employing the residual house spray-

[1] From the Communicable Disease Center, Public Health Service, Bureau of State Services, U. S. Department of Health, Education, and Welfare, Savannah, Georgia.

ing technique are insect resistance to insecticides and the sorption of insecticides by certain types of mud used in house construction in many parts of the world. Resistance is an extremely serious problem. Nine important vectors of malaria and *Aedes aegypti* are resistant to one or more of the insecticides usually used in residual house spraying. Fortunately, in most areas, these species are still susceptible to at least one residual type chlorinated hydrocarbon insecticide. However, in Greece, *Anopheles sacharovi* is resistant to DDT, dieldrin, and chlordane (Livadas, 1955), and in Lebanon the same species is resistant to DDT and dieldrin (Busvine, 1955). Much additional research on this problem is needed if the present advantage in this fight against disease vectors is to be maintained. In that respect, it might be mentioned that in laboratory tests by the Communicable Disease Center at Savannah, Georgia, malathion, parathion, EPN, and combinations of them with DDT, have shown considerable promise as possible substitute insecticides against anophelines resistant to chlorinated hydrocarbon insecticides.

The sorption of insecticides by mud walls is a phenomenon reported from numerous localities in many parts of the world. Contrary to earlier reports (Downs, *et al.,* 1951) that sorption was accompanied by chemical decomposition of the absorbed insecticides, Barlow and Hadaway (1955) have demonstrated rather clearly that the rapid disappearance of insecticidal residues from treated mud surfaces is a physical process of sorption. Bordas and Navarro (1955) later reported observations that the toxicity of dieldrin on mud surfaces in Mexico increased steadily as the relative humidity increased. Burnett (1956) in Africa also reported changes in mortalities of mosquitoes exposed to dieldrin on mud surfaces in relation to seasonal differences in rainfall. Barlow and Hadaway (1956) and Miles and Pearce (1957) have confirmed the fact that the sorption process is affected rather drastically by humidity. Low humidity rates increase the speed of penetration of the insecticide into the mud with consequent decreasing kills of insects. High humidity rates slow down the penetration of the insecticide into the mud, thereby prolonging the effectiveness of a treatment. If sorption has already taken place, high humidity rates cause the insecticide to move back toward the surface of the mud, with resultant increasing kills of insects. Barlow and Hadaway (1956) also found that the structure of the mud surface affected the sorption of insecticides. Paulini (1956) confirmed the physical nature of the sorption phenomenon and showed that the colloidal mineral fraction of mud is the component responsible for its sorptive power, the higher the content of mineral colloids the greater the sorptive power.

While the knowledge gained on the nature of the sorption phenomenon is increasing steadily and will undoubtedly aid in surmounting this problem, the fact remains that it still is a serious problem to be overcome if malaria eradication is to be practicable in large areas of the world. Some of the best industrial and governmental research laboratories in the world are now working on this problem, and it can be hoped that a practical solution to it will be forthcoming.

In addition to indoor spraying for mosquito vectors of disease, residual sprays may be used outdoors also to control adult mosquitoes. Bidlingmayer and Schoof (1956) found that residual treatment to the outside, lower portions of houses and to the shrubbery, grass and other vegetation within a radius of approximately 100 feet of the dwelling gave significant reduction in daytime annoyance from salt-marsh mosquitoes for periods of 1 to 9 weeks. Applications were made with 1.25 percent emulsions at the rate of 5 to 10 lbs. of DDT per acre. BHC (1.3 lb. gamma isomer per acre), dieldrin (4 lbs. per acre), and lindane (1.5 lb. per acre) were relatively ineffective. In later studies (CDC, 1957), Diazinon and malathion at 2 lbs. per acre were also found ineffective. Variations in the duration of effectiveness of the DDT treatments were attributed to mosquito potential, more frequent treat-

ments being required whenever weather conditions permitted excessive mosquito production.

Space spraying for adult mosquito control is an operation of old standing. It also is an activity which has developed tremendously since the old days of "Quick, Henry, the Flit." From that lowly start of occasional household spraying with a relatively standard pyrethrum formulation in a simple hand atomizing type of sprayer, the use of space sprays for the control of adult mosquitoes has become a highly organized, almost nation-wide operation involving a complex combination of equipment, techniques, and materials. It represents the principal use of insecticides by many of the organized mosquito abatement districts and is the only method used by an even greater number of communities which attempt to reduce adult mosquito annoyance without the benefit of an established mosquito abatement organization. In addition to these relatively large-scale outdoor space spraying activities, there is an even more widespread use of indoor space sprays by individuals for the control of adult mosquitoes. In 1955, the annual civilian spending for insecticides for household use in the United States approached $75,000,000—largely through such retail channels as drug stores and grocery stores (NPCA 1956). Almost any large retail store dealing in general household items in this country and a large percentage of gasoline service stations carry in stock a wide variety of insecticidal formulations for adult mosquito control in homes—sprays, aerosol bombs, smoke or fog generators, and so forth—not to mention repellents.

The most casual review of the literature will show that an extremely wide variety of insecticides, dosages, and formulations have been used in outdoor space spraying operations for adult mosquito control, as well as in equipment and methods for applying them. DDT has been and still is the most commonly used insecticide for this purpose. In areas where some species have become resistant to DDT, practically every other recently developed chlorinated hydrocarbon insecticide has been used to some extent (Ginsburg, 1956), including chlordane, toxaphene, DDD, dieldrin, BHC, lindane, heptachlor, and aldrin. Pyrethrum, allethrin, lethane and thanite have been used alone or in combination with the chlorinated hydrocarbons. As multi-resistant strains of mosquitoes have appeared, particularly in California and Florida, attention has shifted to the organophosphorus compounds, of which malathion is the one most commonly used.

There are almost as many dosages and formulations used in outdoor space spraying as there are operating units or agencies employing this method of adult mosquito control. There are no such things as standard formulations or dosage rates. They vary according to species of mosquitoes, geographical area, type of application employed, weather conditions, and the opinions of the individual operators. DDT is used most commonly as a 5 percent solution in fuel oil, applied at approximately 0.5 lb. per acre. The other chlorinated hydrocarbons are also used generally in some type of fuel oil solutions at dosages ranging from 0.1 to 0.5 lb. per acre. Malathion likewise is used at dosage rates of 0.1 to 0.5 lb. per acre.

The equipment for applying outdoor space sprays also varies greatly from small portable ground units to helicopter and C-47 aircraft units specially designed for the purpose. Here again, the type of equipment and method of application vary according to terrain, weather, size of area, type of area, mosquito species, and the whims of the individual operators. New variations of existing equipment are constantly being developed by many individuals to meet their own specific needs. Equipment which gives superior performance under one set of field conditions may be inferior to other equipment under other conditions. Each operator must carefully evaluate the conditions under which use is planned and select his equipment, insecticide and formulation to meet those particular needs.

A specialized use of insecticides to control adult mosquitoes is in the disinfesta-

tion of aircraft used in international traffic. The quarantine regulations of most countries of the world require that aircraft entering their countries be disinfested. Health authorities have always been most interested in avoiding the importation of exotic mosquito vectors of disease. With the attainment of malaria eradication in large areas of the world and the growing development of resistant species of malaria vectors, interest in aircraft disinfestation may be expected to increase in the future. Aerosols of DDT and pyrethrins are the most widely accepted method of aircraft disinfestation now used throughout the world. These are not completely satisfactory, however, and improved methods are needed. Some promising research is now in progress at the Communicable Disease Center laboratory at Savannah, Georgia, involving the possible use of insecticidal vapors or short-lived residuals applied with insecticidal vapors.

While insecticides for the control of adult mosquitoes have their place in most mosquito control programs, they are, at best, a temporary expedient. Part of every operating program should be directed toward more permanent solutions to the problem. We have such problems as resistance and sorption of insecticides by mud walls only because we have large numbers of mosquitoes to create such control problems. No species has ever developed resistance to an absence of breeding places. The elimination of mosquito breeding sources should be foremost on the list of control methods employed.

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STUDIES OF MOSQUITO RESISTANCE TO INSECTICIDES AT SOME NAVAL ACTIVITIES [1]

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GENERAL INFORMATION. Two members of the U. S. Navy Disease Vector Control Center arrived at the U. S. Naval Station, San Juan, Puerto Rico, on 6 September 1955 for the purpose of conducting studies on reported resistance to DDT of the southern house mosquito, *Culex quinquefasciatus*. This study was requested by the Commandant, Tenth Naval District.

The resistance tests conducted by members of this Center were purposely limited to mosquito larvae. Because of the limited time and facilities no attempt was made to approach the problem through study of adult populations. It is pointed out, however, that the finding of true physiological (genetical) resistance in immature stages ordinarily implies, *per se,* resistance in the adult population since this character or factor or the capacity therefor is passed through succeeding generations.

TESTING TECHNIQUE. The technique used for the determination of insecticide resistance in mosquito larvae in this investigation was the technique established by the U. S. Department of Agriculture, Agricultural Research Service, Entomology Research Branch, Orlando, Florida.

FINDINGS. Table 1 gives the results of tests conducted on larvae collected in the San Juan, Puerto Rico, area.

The tests are to be considered as preliminary in nature; nevertheless the results are highly indicative of true resistance in the populations tested. In several of the tests the 48-hour mortality was very high in the control group. Where possible, these tests were repeated. Several tests could not be repeated for one of two reasons: either an insufficient number of larvae were available from the same location, or time did not permit returning to outlying areas to collect additional larvae.

The results of these tests strongly indicate the presence of resistance to DDT in the *C. quinquefasciatus* populations tested.

One test made with dieldrin indicates the *C. quinquefasciatus* strain tested may also be resistant to this insecticide. This is entirely possible in view of the fact that larvae have been repeatedly and extensively exposed to this material as the Insular Health Department was using dieldrin as a larvicide in the mosquito control program throughout the San Juan area.

It was recommended that the Navy's civilian entomologist conduct additional confirmatory larval tests on *Culex quinquefasciatus* using the same insecticides and techniques.

CONCLUSIONS. These tests establish strong positive presumptive evidence of the presence of DDT resistance in most *C. quinquefasciatus* larval populations encountered. This resistance is probably passed on to the adult stage and so to succeeding generations. Field observations by personnel of the mosquito control program of the Puerto Rico Insular Health Department and the U. S. Public Health Service have led them to believe that *C. quinquefasciatus* adults have been resistant to DDT for several years. The 1951–1952 annual report of the Insular Health Department stated that *C. quinquefasciatus* was resistant to DDT. To our knowl-

[1] The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

TABLE 1.—Toxicity of acetone suspensions of some chlorinated hydrocarbon insecticides to fourth instar mosquito larvae.

Location	Total Replicates	Concentrations PPM	Corrected Percent 48-hr. Mortality	USDA Standard Non-resistant Strain	USDA Standard Resistant Strain
U. S. Naval Station,* San Juan, Puerto Rico	2	0.05	25.8	–	–
		0.025	17.9	86–100	–
		0.01	11.1	62–100	–
San Patricio* (Housing) Puerto Rico	2	0.1	48.2	–	–
		0.05	53.8	–	–
		0.025	48.2	86–100	–
		0.01	58.5	62–100	–
Martin Pena* U. S. Navy Radio Factory	1	0.1	12.0	–	–
		0.05	12.0	–	–
		0.025	16.0	86–100	–
		0.01	16.0	62–100	–
Santurce* Puerto Rico	3	0.1	56.4	–	–
		0.05	41.6	–	–
		0.025	36.5	86–100	–
		0.01	17.9	62–100	–
Key West and environs**	7	0.1	42.0	–	66–100
		0.05	18.0	82–100	39–84
		0.025	30.0	68–100	68–100
		0.01	30.0	51–100	0–60
Key West and environs***	3	0.025	7.0	88–100	48–100
		0.01	28.0	84–100	44–87
		0.005	34.0	36–100	16–66
Key West and environs****	4	0.025	36.0	98–100	80–100
		0.01	15.0	82–100	36–100
		0.005	15.0	56–100	16–96

* Tests with DDT against *Culex quinquefasciatus* fourth instar larvae.
** Tests with DDT against salt marsh *Aedes* spp. fourth instar larvae.
*** Tests with lindane against salt marsh *Aedes* spp. fourth instar larvae.
**** Tests with dieldrin against salt marsh *Aedes* spp. fourth instar larvae.

edge this statement was not substantiated by laboratory or field data.

U. S. NAVAL BASE, KEY WEST, FLORIDA

GENERAL INFORMATION. A field party consisting of a medical entomologist and one environmental sanitation technician from this Center arrived at the U. S. Naval Base, Key West, Florida on 26 September 1956 for the purpose of investigating resistance in salt-marsh mosquitoes, *Aedes* spp., to the chlorinated hydrocarbon insecticides which had been used for control operations in that area over a period of several years.

The manager of the Monroe County Mosquito Abatement District was contacted and the resistance problem was discussed with him. No studies of this nature had been attempted by that organization. Preliminary information on the effect of certain insecticides applied as aerosols on adult salt-marsh mosquitoes of the Key West area has been reported by Warner.[1] Resistance has previously been

[1] Warner, W. M. 1956. A preliminary report on the chemical control of the salt-marsh *Aedes* with thermal aerosol apparatus on the Florida Keys. Rpt. of the 27th Ann. Mtg. Fla. Anti-Mosq. Assoc. pp. 126–39.

reported in salt-marsh mosquitoes from certain localities in Florida.[2]

The resistance tests conducted by personnel of this Center were purposely limited to mosquito larvae. Because of the limited time and facilities no attempt was made to approach the problem through study of adult populations.

TESTING TECHNIQUE. The testing technique used was the same as previously described. Field collected, fourth instar *Aedes* salt-marsh mosquito larvae were used throughout. No effort was made to identify and differentiate between the *Aedes sollicitans* and *Aedes taeniorhynchus* due to the fact that the standards were established not for the individual species but rather for the salt-marsh *Aedes* group as a whole.

FINDINGS. Table 1 summarizes the results of tests conducted with larvae collected in the Key West Navy area. Extensive, careful field surveys on Key West, Boca Chica Key, Geiger Key, Big Coppitt Key and Stock Island revealed only three locations with larvae in sufficient numbers for tests. Two factors may explain this. A period of heavy rains had occurred prior to the field party's arrival and these continued during the first three days of the visit. High tides had also inundated a number of areas not ordinarily affected by normal tides.

Although the results of these tests were considered as preliminary in nature, they were nevertheless highly indicative of true insecticide resistance in the populations tested.

In one location the number of larvae collected was sufficient to make three replications each with DDT, dieldrin and lindane. In a second location enough larvae were collected for three tests with DDT and one with dieldrin. The results of all tests indicate that the salt-marsh *Aedes* populations encountered are significantly resistant to this group of chlorinated hydrocarbon insecticides. This is entirely possible in view of the fact that either DDT, BHC or dieldrin have been used repeatedly and extensively in all the areas in question for adult and larval control operations over a period of at least eight years. During the 1956 season no synthetic insecticides had been used in larval control operations. Diesel fuel oil had been used for this purpose.

Additional confirmatory tests were to be made by Medical Department personnel assigned to the Base Sanitation Office with the insecticides DDT, dieldrin and lindane (and possibly others) using the same techniques.

CONCLUSIONS. The tests reported here establish strong positive presumptive evidence of the presence of resistance to the chlorinated hydrocarbon insecticides by salt-marsh *Aedes* in the Key West navy area. This resistance is probably passed on to the adult stage and so to succeeding generations.

[2] Public Health pesticides, 1956 report from the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education and Welfare. Pest Control 24(3):9–10 et seq.

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LARVICIDE TESTS AGAINST BLACKFLIES IN SLOW-MOVING STREAMS

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Considerable research has been conducted on the control of blackfly larvae (*Simulium* spp.) breeding in swiftly flowing mountain streams. Fairchild and Barreda (1945) obtained complete eradication of these insects for distances up to 10 kilometers in mountain streams in Guatemala with 60-minute applications of DDT at 1 p.p.m. Garnham and McMahon (1947) reported the elimination of larvae from an area in Kenya Colony, East Africa, with DDT at 1 to 27 p.p.m. Kindler and Regan (1949) reported nearly complete control in a 5-mile section of a New Hampshire stream with TDE introduced at 1 p.p.m. for 10 minutes at 1-mile intervals. Gjullin *et al.* (1949) found DDT to be the most effective of several insecticides tested against blackfly larvae in Alaska. They obtained complete control for distances up to 880 yards with DDT at 0.3 p.p.m. after 15-minute application periods. However, the control of blackflies breeding in sluggish streams that drain swamps of the southeastern United States has until recently received very little attention.

In 1954, 1955, and 1956 field investigations were conducted to evaluate DDT, dieldrin, and parathion for the control of blackfly larvae in Florida and South Carolina streams where the water velocity varied from no measurable movement to 2.5 feet per second. These meandering streams were located in heavily wooded, relatively flat terrain, and varied considerably in width, depth, and rate of flow. They had sand or mud bottoms, many deep pools, and pondlike enlargements, and contained two or three types of aquatic plants. Riffles formed by logs, roots, accumulations of brush and leaves, and a few slight changes in elevation provided practically all the breeding areas. The species encountered in these areas were *Simulium slossonae* D. & S., *S. congareenarum* (D. & S.), *S. decorum* Wlkr., the species comprising the *S. venustum* complex, and *Cnephia pecuarum* (Riley). The *S. venustum* complex includes true *venustum* Say, *tuberosum* (Lundst.), and *verecundum* Stone and Jamnback.[1] This closely related group can only be distinguished by the male genitalia. None of these species are injurious to man in these localities, but *slossonae* and *congareenarum* are frequently serious pests of turkeys. Jones and Richey (1956) reported *slossonae* to be a vector of a leucocytozoon disease in turkeys. This was the prevalent species in Florida.

The insecticides were evaluated by comparing pretreatment and post-treatment counts of larvae attached to dead leaves, sticks, and green aquatic vegetation at one or more places downstream from the application site. In some tests the control was determined for only a few days, but in others counts were made for several weeks.

Ground Tests. In 1954, tests were conducted in South Carolina to compare the effectiveness of DDT applied as an emulsion, as an oil solution, and as granules. A DDT emulsifiable concentrate was introduced for 15 minutes from a dripping apparatus that delivered approximately 50 ml. of liquid per minute. A 5 percent solution of DDT in fuel oil was applied with a hand sprayer and 5 percent granules on 16/30-mesh bentonite were scattered by hand on 30-foot sections of streams.

In 1956, other tests were run in Florida and South Carolina streams to compare DDT emulsions with two parathion form-

[1] Alan Stone, of the Entomology Research Division, determined the many specimens submitted during these studies.

ulations. Parathion was applied as a solution in isopropanol and as a solubilized concentrate containing 1 part of parathion to 4 parts of Triton X-100. Various concentrations of both toxicants were introduced into the water for 5, 10, 20, and 24 or 30 minutes with a dripping apparatus that delivered 100 or 200 ml. of liquid per minute.

The dripping apparatus treatments were applied at points where the water surface was not smooth in order to obtain as much agitation and mixing as possible. No attention was paid to this factor in the tests with fuel oil and granular formulations, as these treatments were intended to simulate airplane applications. The flow of each stream in gallons per minute was estimated by timing the water movement for a predetermined distance in areas where the width and depth were easily determined. A small cork, liquid dye, or a simple Pitot flowmeter was used to assist in ascertaining the flow rate.

Because of the swampy terrain, the heavy, tangled undergrowth, and the nonuniform distribution of blackfly breeding sites, these tests could not be checked at uniform distances downstream, but observations were made wherever accessible breeding was found.

The tests showing the relative effectiveness of the three DDT formulations are presented in Table 1. All were effective for at least short distances. The emulsion and oil solution at 0.1 p.p.m. caused complete detachment of larvae within 24 to 48 hours for distances up to 400 yards downstream. No effective control was apparent in one stream after 880 yards. The granules at 1 pound per acre eliminated all larvae for at least 193 yards, but the 0.5 pound treatment was ineffective at the single point examined, 250 yards below the introduction site.

The results of the tests conducted in 1956 to compare DDT with parathion appear in Table 2. In Florida, 5-minute applications of parathion at 0.5 and 1 p.p.m. eliminated all the larvae for 0.6 to 1.6 miles in two streams, but 5- to 24-minute applications failed to give good control at 2.3 or 6 miles. In South Carolina 10- to 20-minute applications of parathion at 0.5 and 1 p.p.m. gave 100 percent reductions at 0.24 to 2.8 miles. One

TABLE 1.—Relative effectiveness of various DDT formulations against blackfly larvae in South Carolina streams. 1954

Formulation and Dosage	Station Distance (Yards)	Pretreatment Count [a]	Percent Detachment in 24–48 Hours
Emulsion			
0.1 p.p.m.	50	47	100
	100	50	100
	880	22	9
	20	65	100
	140	218	100
	218	120	100
	268	500	100
Oil solution			
0.1 p.p.m.	60	45	100
	200	62	100
	400	13	100
Granules			
0.5 pound per acre	250	41	0
1.0 pound per acre	83	500	100
	133	500	100
	193	500	100

[a] Average per attachment unit (stick, leaf, or blade of aquatic grass).

TABLE 2.—Relative effectiveness of parathion and DDT as blackfly larvicides applied with an automatic applicator.

Insecticide	Dosage (p.p.m.)	Carrier	Treatment Time (min.)	Stream	Station Distance (miles)	Pretreatment Count[a]	Percent Detachment in 24 Hours	48 Hours	72 Hours
				Florida Tests					
Parathion	0.5	Triton X-100	5	1	1.6	18	100	—	—
		Isopropanol	5	2	6.0	21	0	0	0
				3	2.3	13	45	45	—
			10	3	2.3	76	40	40	—
	.74	"	24	3	2.3	36	0	0	0
	1.0	Triton X-100	20	3	2.3	36	0	0	0
			5	2	.6	16	100	—	—
DDT	1.0	Xylene +	5	4	1.5	26	0	0	—
		Triton X-100	20	4	.27	21	96	100	—
					.30	29	74	48	—
					.31	56	0	0	—
	3.4	"	5	4	.04	10	100	—	—
				South Carolina Tests					
Parathion	.5	Isopropanol	5	5	.57	42	100	—	—
				6	.57	41	100	—	—
					1.5[b]	50	0	40	40
					1.5[c]	135	0	96	96
		Triton X-100	5	7	1.5	100+	0	0	0
					2.75	9	0	0	0
			20	8	1.5	49	80	100	—
	1.0	Isopropanol	10	9	.24	13	100	—	—
		Triton X-100	20	7	1.25[b]	4	0	100	—
					1.25[b]	9	0	100	—
					1.25[c]	58	0	99+	100
					2.5	130	0	0	0
				10	2.8	33	100	—	—
DDT	1.0	Xylene +	10	11	.28	42	99+	99+	—
		Triton X-100	20	12	2.0	19	0	0	0
			30	13	.25	14	100	—	—
					2.25	111	0	0	0

[a] Average per attachment unit (stick, leaf or blade of aquatic grass). Counts were made during each observation period in similar untreated streams with counts ranging from 5 to 100+. The abundance of larvae never declined in the untreated streams.

[b] Small branch of main stream.

[c] Main channel of stream.

20-minute treatment gave 100 percent control for 1.25 miles, but none after 2.5 miles. Five-minute applications at 0.5 p.p.m. were effective for 0.57 mile, and partially effective at 1.5 miles in one test, but ineffective at 1.5 miles in another. In both States, DDT at 1 p.p.m. for 10 and 20 minutes was effective for distances up to 0.28 mile in some tests, but not at 0.3 mile or more in others. Dilution of the insecticide in the large and small pools present in streams of this type was undoubtedly a factor in destroying the effectiveness of the insecticide. The slow rate of movement in these streams is indicated in one test, in which a treatment of parathion at 1 p.p.m. gave 100 percent control at the 2.2 mile and 0 at the 2.8-mile point after 21 hours, but 100 percent at the 2.8-mile point after 24 hours.

AIRPLANE TESTS. Tests were conducted in South Carolina in March 1955 to evaluate aerial applications of DDT and dieldrin as larvicides. A 5 percent solution of DDT in fuel oil was applied to plots of 11 and 4 square miles at the rate of 2 quarts per acre with a Stearman airplane. The plane flew 90 m.p.h. at an altitude of 100 feet to produce a swath width estimated to be 100 feet. Wind velocities varied from 3 m.p.h. to occasional gusts up to 15 m.p.h. Granules containing 7 percent of dieldrin on attapulgite were applied to a plot 1 mile square with a Piper Cub plane flying 75 m.p.h. at an altitude of 100 feet. This plane was calibrated to deliver 40 pounds of granules per mile with an effective swath of 25 feet. All treatments were applied in strips by flying swath intervals of 200 yards across the entire area included in the test. Much of the material fell on dry land, but it was hoped a large part of it would eventually reach the streams and in that way control the insects for several months. Counting stations were established at 10 points in the large plot and 5 points in the two smaller ones. The results are given in Table 3.

The DDT spray applied to the large plot gave almost 100 percent control for 2 weeks, and then gradually lost its effectiveness. In the small plot the control rose gradually to 95 percent after 1 week, but dropped to 87–88 percent in the third and fourth weeks. The dieldrin granules completely eliminated larvae for 2 weeks, and the control remained considerably above 90 percent through 4 weeks. Then a drought reduced the water level and breeding in all streams, and the tests were discontinued.

SUMMARY. Field investigations were conducted to evaluate DDT, dieldrin, and parathion for the control of blackfly larvae (*Simulium* spp.) in slow-moving streams in Florida and South Carolina.

In Florida parathion at 0.5 and 1 p.p.m. eliminated all larvae for distances up to 1.6 miles in two streams after 5-minute treatment periods, but failed to give good control after 2.3 miles in five others with treatments for 5 to 24 minutes. In South Carolina 10- and 20-minute applications

TABLE 3.—Control of blackfly larvae with aerial applications of DDT sprays and dieldrin granules.

Treatment	Dosage (lb./acre)	Average Pretreatment Count [a]	Number of Counts	Percent Reduction at Indicated Interval after Treatment					
				24 Hours	48 Hours	1 Week	2 Weeks	3 Weeks	4 Weeks
DDT solution [b]	0.2	7.1	380	99+	99+	99+	99+	72	68
Do.[c]	.2	4.1	195	86	86	95	95	87	88
Dieldrin granules	.04	87.2	25	100	100	100	100	94	98
None (check)	—	75	10	0	0	—	0	0	0

[a] Average per attachment unit.
[b] 11 square miles.
[c] 4 square miles.

gave 100 percent reductions for distances up to 2.8 miles before the insecticide was diluted in large pools or by tributary streams. The greatest distance at which DDT was effective was 0.28 mile.

A 5-percent DDT solution in fuel oil applied with an airplane to 11- and 4-square-mile plots at 2 quarts per acre gave 95 to 99 percent control for 2 weeks, and then gradually lost effectiveness. Aerial applications of granules at 0.04 pound of dieldrin per acre eliminated blackfly larvae for 2 weeks, and the control remained considerably above 90 percent through 4 weeks.

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EFFECTIVENESS OF DITCHING IN CONTROLLING SALT-MARSH MOSQUITOES

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The degree of effectiveness of ditching in controlling salt-marsh mosquitoes is dependent on many factors, but the most important is the planning and forethought given to the problem before the ditches are constructed. Ditches, if they are to be effective, must be planned and designed to fit the problem area. The plans of any project must take into consideration all the factors which will affect the outcome and determine the economy. To ditch any given area is one thing, but properly to place the minimum length of ditches, to give the maximum control at a minimum of cost is a well-designed source reduction project.

We all realize that the problem is the rains and tides which cause intermittent flooding on the marsh. The question whether it is more economical to keep the water on the marsh or to get it off, must be decided in arriving at a solution. If the ground conditions, pumping cost or some other factor prohibits the use of flooding, the use of ditching will most probably be the method most economically feasible. The engineering design of a ditching problem must be preceded by an entomological survey of the area in question. A complete entomological survey showing where the mosquitoes are breeding under various conditions should be the governing factor in any well-designed project. For example, the salt-marsh mosquitoes have been observed breeding in the salt flats which separate the mangrove areas from the higher palmetto land when no breeding was occurring in the mangroves, and vice versa. When the area is flooded by tide, some areas may breed; and when flooded by rain, other areas may be involved. This knowledge of an area should determine where in the marsh the ditching efforts should be concentrated. I have read somewhere a statement which said that only one-fifth of the salt-marsh

area in Florida breeds mosquitoes. If this statement is true, then four-fifths of our problem is eliminated by the entomological survey, and time, money, and ditches can be put into the areas where they will do the most good.

Having defined the problem area brings up many questions the mosquito control director must answer before the program gets under way. First, what type and kind of equipment to use? In Florida our problem is so varied that we range from ball-bearing sand in northern and western Florida to soft rock in Dade County, where the ditches can be cut 18" wide and 6 ft. deep and will hold up satisfactorily. The equipment must conform to the type of terrain in which it is to work. The most typical in Florida is the mangrove swamps with salt flats. Experience has shown us in Florida that the most economical piece of equipment to use in this type area is a ¾ cubic yard dragline. A dragline of this size has the endurance and power needed to work in the mangroves—yet it is light enough to work on mats in areas where it is impossible to walk. Mr. Stutz, in Dade County, has been using a ditching machine and getting good results, but the conditions must be just right in order to obtain peak productivity. The type and size of equipment selected should be governed by productivity and economy of that equipment when operated in the problem area.

The width, depth and location of ditches is also subject to much discussion on what is needed or what is best. A mosquito control ditch in a salt marsh should be wide enough to function properly not only when constructed but years later when the vegetation has readjusted itself to the new surroundings. During the days of WPA, many ditches were small and hand-constructed; they have now grown over or filled up. The effectiveness of the ditches is lost, and in many cases they themselves are breeding mosquitoes.

Ditch maintenance is an expensive undertaking and frequently costs as much as, or more than the original ditch. It is anticipated that by the use of larger ditches, maintenance cost can be eliminated or reduced. In mangroves, for instance, no ditch should be constructed less than 10 feet wide and preferably 12 feet under heavier conditions. The mangroves will grow back on the ditch banks and will block approximately 3 feet on each side with their vast root systems and overhanging boughs. This would leave a 4 to 6 foot open channel that could function properly for years as a mosquito control ditch.

In areas where vegetation is light, a smaller ditch could be dug, but it should always be large enough to prevent it from being stopped up by debris and logs. Large ditches are indicated where large quantities of water must be drained from incoming and outgoing tides and where heavy rainfall must be immediately drained. The larger channels do, however, increase the cost and also provide another problem in the placement of the spoil dirt. The spoil dirt should be piled and staggered in its placement, first on one side of the ditch and then the other and small laterals constructed between the spoil piles to prevent blocking the water from the ditch. The utilizing of the spoil dirt to fill low areas adjacent to the ditch line is not only a costly operation but a dangerous one, from a mosquito control standpoint. If proper grade is not maintained in leveling the spoil, new breeding areas can be created; also the leveled spoil can prevent the surface water from reaching the ditch and lessen the effectiveness of the ditch.

The depth most commonly used in mosquito control ditches in Florida is one foot below mean low tide. This provides a ditch which has water in it at all times and provides a reservoir for the minnow population during low tides. The ditches in many areas are referred to as "minnow access canals." Where there is only a small variation between high and low tides, the function of the ditch for tidal flushing action is decreased, but it is still effective as a minnow access ditch. By

constructing the ditch to this depth, the water from the surrounding marsh not only is removed from the surface, but a lateral movement of underground water flows into the ditch. This lowers the water table in the marsh and makes the marsh capable of receiving more rain water without ponding and presenting a breeding problem.

The ditches that are now being constructed in Florida are located from an effectiveness point of view. Very few straight canals are laid out at various intervals to give a mass coverage of an area. The ditches are placed in the lowest areas of the marsh and follow the swales and natural runs through the marsh. All low areas and outlying pockets of water are tied into the canal system. This may present a maze of ditches over the marsh area, but it has proven to be the most effective in eliminating the greatest percentage of breeding. In designing a ditching layout of this type, aerial photos and actual flights over the project area are very helpful. The more outlets connecting the ditching system to open water, the more effective and long lasting the effects that can be expected from the control project. Utilization of the natural streams for outlets prevents costly constructions which might otherwise be necessary to keep the mouths of the ditches open. Care in selecting the position of the ditch opening into an open body of water is necessary. The opening should avoid subjection to wave action where possible.

In designing a ditching system connecting all the swales and natural low areas, the director can only lay out his main canals and so-called "skeleton" ditches. These ditches will bring the tide into the marsh, and also take the tide and rain water off the marsh. Many small laterals will have to be constructed from this original skeleton of ditches to tie in the aforementioned outlying areas. The most important man in selecting and placing of these laterals is the dragline operator. His ability to perform this duty will greatly increase the effectiveness of the ditching system. The dragline operator should be trained not only to operate his machine but to be able to locate prime breeding areas within the marsh. Time spent by any director to train his operators in this way will be reflected in the effectiveness of his program. An operator trained in locating the breeding areas can connect these areas into the ditching system so as to eliminate completely the area as a breeder. He can also relocate the ditches when conditions in the field indicate that more effective control would result.

There are many factors in dragline ditching which govern the quantity of work performed. The care and maintenance given a machine results in fewer breakdowns and less time lost. The enthusiasm of the operator and his knowledge of the problem increase productivity. In the battle of man versus mosquito, time is important. Many districts have set up goals to eliminate a large percentage of their salt-marsh breeding area in a given number of years. Some districts are able to produce a larger quantity of work under similar conditions than others, but all directors should strive to obtain maximum production with the equipment they have.

In the last three years, approximately 1,000 miles of mosquito control ditches have been constructed in Florida. These ditches were dug in salt-marsh areas in the manner described above and have eliminated better than 25,000 acres of prolific salt-marsh breeding area. True, it is a slow job and a seemingly endless one in some areas. In one county in Florida, approximately 90 percent of the salt-marsh breeding has been controlled by ditching operations in a four-year period. Other counties and districts are making similar progress. By carefully selecting the projects producing the most mosquitoes which are affecting the most people, the effects of permanent control methods are being noticed. In one of the distircts in Florida last year, a large build-up of mosquitoes had the county declaring itself a disaster area, which brought help from local, State,

and Federal agencies. In the area in this district which had been ditched, no mosquito larvae could be found, but the unditched areas were producing the hordes of mosquitoes. In a recent release by Mr. Mulrennan, he made the statement that where salt-marsh areas have been ditched, the mosquito breeding has been reduced to zero in most areas. All directors of mosquito control districts where machine ditching has been in operation for a year or two can vouch for the reduction of mosquitoes in the areas worked.

Mosquito light trap collections have been recorded by the Bureau of Entomology for the past eight years. The permanent control program emphasis began in Florida four years ago, so we have collections for four years before and four years after the program began. Many factors are to be considered in comparing one trap collection with another or even one area with another. For comparison, I have taken an average count of salt-marsh mosquitoes per collection for each year. There has been a steady decline in salt-marsh mosquitoes per collection. The four years since the permanent program began, show a 42 percent reduction in salt-marsh mosquitoes over the four years prior to its start. This reduction is based on the results of about 6,000 collections each year during the period and was confined to the coastal counties and districts where salt-marsh mosquitoes are a problem. This, in my opinion, is proof positive of the effectiveness of ditching in controlling salt-marsh mosquitoes.

Research is now being planned and carried out whereby our present methods can be improved, and methods of speeding operations and productions are being integrated into the programs. If the present pace of eliminative control is maintained, many areas in Florida will find themselves virtually free of salt-marsh mosquitoes.

MINIMIZING MOSQUITO BREEDING IN IRRIGATED PASTURES

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As a source of mosquitoes, water used for irrigation would seem, at first glance, to present a rather unique problem to the mosquito control worker. For example, most mosquito breeding places, such as the backyard tin can, the clogged eaves trough, the industrial by-product waste water, the sewage settling pond, the swamp or salt marsh, are also undesirable for other reasons. The simplest way to minimize mosquito breeding in them is to eliminate them, and allies can usually be found who are anxious to cooperate to that end.

Irrigation water, on the other hand, represents the livelihood of a large and important segment of our population, and the foodstuffs produced through its use feed much of the world. It is transported hundreds of miles and pumped up thousands of feet, arriving at its destination not by accident, but through concerted effort, and is deliberately placed in the field where it becomes a mosquito source. This might appear to be a variety of mosquito-breeding place about which little could be done in the way of minimization.

Fortunately, however, *water used for irrigation presents no mosquito problem.* Water actually in use for plant production, except in the case of rice, is below the surface of the soil, in the root zone of the crop, and can obviously produce no mosquitoes there. To quote from California Agricultural Experiment Station Circular

439, *Mosquito Control on the Farm,* "Water standing on fields for excessive periods of time reduces crop yields, encourages the growth of water-loving, weedy plants, presents an unhealthy environment for livestock, and may do injury to the soil. Water which stands on fields for more than 24 hours after irrigation is of no benefit to crops—but water standing for 24 or even 48 hours, will not produce mosquitoes."

It is the water *mis*-used and wasted which breeds mosquitoes, and this fact puts it right into the same category as the other sources mentioned above, as undesirable water which can and should be eliminated.

The foregoing statements, while referring to all irrigated lands in general, apply even more strongly to irrigated pastures in particular. With the possible exception of rice fields, pastures are the most prolific mosquito producers of all irrigated lands, and for a very simple economic reason. With most other crops, the plants grown are the direct means of livelihood of the farmer, pure stands pay best, and annual incomes are directly and obviously related to per-acre yields. Pasture grasses, on the other hand, are secondary crops. The farmer's income is derived from the sale of milk, meat, or animals, not plant materials, and the relationship between this income and the per-acre yield of the land is indirect and less obvious.

When, because of excess water standing on the surface of a field, a stand of cotton, alfalfa, tomatoes, or other money crop begins to drown out, the damage is immediately obvious, and so is the cure. The farmer quickly takes the necessary steps to get rid of the water, not to prevent mosquito production but to protect his pocketbook.

However, when the same thing occurs in an irrigated pasture, it is far less obvious, even to one as intimate with the land as the man who is operating it. Pastures are usually mixed stands to start with, and therefore present a heterogeneous appearance at best. When the original grasses drown out they are quickly replaced by water-loving weeds which, until a full-fledged swamp has developed, give the impression, to a hasty glance, that feed is being produced throughout the field. And most of the time a hasty glance is all they get, because the farmer is looking at the livestock in the field, not at the individual plants underfoot. Unfortunately, these animals do not reflect the low-grade quality of the feed too obviously, supplementary feeding often obscures the picture, and there seldom is a good direct comparison to be drawn between these animals and those produced on a field without standing water, other factors being equal. Where such comparisons have been possible, they almost invariably point up the economic value of eliminating the excess water. The Crocker-Huffman Land and Cattle Company of Merced, California, for instance, has been able to demonstrate a consistent fifty pound per head advantage at time of sale on beef cattle raised in pastures drained by the local Mosquito Abatement District, over those on undrained pastures.

So the allies necessary to cooperate with and help the mosquito control agency in reducing the mosquito breeding in irrigated pastures are potentially available. But they need to be cultivated and developed, and throughout the following discussion of the actual methods of achieving the minimization of pasture mosquito production, it should be constantly kept in mind that education is the best single tool which the mosquito worker has at his command. Most of the means of reducing mosquito sources in pastures are physically beyond the means, legally beyond the power, and ethically beyond the responsibility of the control agency. The only hope of accomplishing them lies in teaching their advantages, showing the individual farmer how they will directly benefit him, and making him want to cooperate in order to improve himself financially, and, maybe, incidentally, to get rid of the mosquitoes. He doesn't really like mosquitoes, but, in too many instances, has

felt that they were just a necessary evil incident to his way of life.

Mosquito breeding in irrigated pastures may be minimized by care in planning of fields and their irrigation systems, by close and constant attention to the quantity of water applied and the method of applying it, by installation and use of a drainage system, or for greatest efficiency, by a combination of all three of these practices.

Careful preparation of pasture-land, prior to seeding, is the method likely to give longest-lasting results as far as both mosquito control and crop production are concerned. It is also the hardest program for a mosquito control agency to sell to the average farmer. Scientific planning and sound engineering in the design of the field's slope, checks, borders, and water delivery and spreading structures, based upon local soil characteristics and water supply factors, pay dividends in better yields and improvement of the land. But they represent a major capital outlay and the farmer who is hard-pressed for cash *because* his yields are low is frequently the most difficult to convince that such an expenditure is justified and will return in increased profits in a relatively short time. This is particularly true, of course, during periods of unsettled food prices, when the farmer is uncertain what his product will be worth over the next few years.

For these reasons, because few mosquito agencies are equipped or financed to perform such major construction work, and because it would be difficult to justify improving an individual's property to such an extent at the expense of the taxpayers, most agencies confine their efforts to improving pasture-land preparation, to pointing out its advantages to the owner, and to making recommendations as to the best means of carrying it out.

The second general method of minimizing mosquito production, the use of good irrigation practices, is also beyond the direct control of the mosquito agency. Historically, the development of irrigated agriculture has been a constant fight to obtain water and water rights. As a result of the fixed devotion to this cause over several generations, it is often difficult to convince the man who has acquired the right to put water on his arid land that it is possible to get too much of a good thing. Cooperative studies made by the California State Health Department's Bureau of Vector Control and the USDA Agricultural Research Service in Merced County, have shown over several years and with a variety of methods of irrigation that the degree of irrigation efficiency (i.e., achieving maximum plant use of available water) has a conspicuous inverse relationship to the numbers of mosquitoes produced. Fields in which maximum plant use was made of minimum quantities of water consistently produced fewer mosquitoes, and most of the water in the fields which produced mosquitoes was wasted as far as the crop was concerned.

Again, the agency's best approach to this aspect of the problem is education of the individual and demonstration that a little less water will produce greater crop yields at less cost.

The third general method of reducing sources of mosquitoes in pastures, and the one in which mosquito control agencies can participate most actively, is drainage of excess water from the fields before it can produce mosquitoes. The best-prepared pasture settles and deteriorates with time, creating water-holding low spots, and the most conscientious irrigator is capable of human error in estimating water flow or the current ability of the soil to take moisture. When these events occur the result is the production of mosquitoes unless some provision is made for removal of excess water.

Machinery used for construction of pasture drainage systems is within the financial capabilites of most agencies, and basically is the same earth-moving equipment used for draining or filling natural swamps or salt marshes. Simple cost accounting shows that expenditures made by the agency in constructing such systems are usually more than made up in savings in spray costs. A few examples of this, from

TABLE 1.—Comparative costs of larviciding before and after drainage in Merced County

	Pasture Area	Larviciding Cost for One Season	Cost of Drainage	Larviciding Cost Season Following Drainage
Case A	1200 acres	$1,275.00	$81.00	$295.00
Case B	100 acres	201.00	52.00	19.00
Case C	33 acres	29.00	11.00	———

the Merced County Mosquito Abatement District records, are given in table 1.

Because again we have the ethical problem of improving an individual's property at the cost of the taxpayers at large, and because under most legal codes, the responsibility for such work is the landowner's, most agencies require financial participation on the part of the owner, usually to the extent of re-paying the operating costs of the machinery used.

Two general methods of disposing of this excess water are widely employed; drainage of the water to a sump from which it is pumped back into the field's irrigation system, and drainage to a natural outlet. A third method, drainage to a so-called "upside-down-well" to put the water into the underground water-table, is sometimes employed, but is not too practical because of the danger of contamination of water supplies and the tendency of these drainage wells to clog with silt.

The re-circulation system, which has been most highly developed by the Kern and Delta Mosquito Abatement Districts of California, has its greatest application in areas where water is scarcest and therefore most valuable. Delta's source reduction program, supervised by a staff engineer, involves the design and engineering of complete systems, at District expense, and the rental, at cost and including operators, of heavy crawler tractors with bulldozers, scrapers, and graders, to construct them. This program has resulted in the minimizing of mosquito breeding on what were previously some of the most prolific mosquito-producing pastures in the area.

The system of drainage to an outlet has probably attained its greatest development in the Merced County Mosquito Abatement District. Because it has the widest general application, and because of the author's familiarity with it, a somewhat more detailed account of this operation will be given here. This system is relied upon in this area for two reasons: first, because water is fairly cheap and available, making it more economical to deliver new water and remove the excess than to pump back and re-use it; and second, because the alkali content of much of our soil and water is so high that it would reach dangerous levels if the drainage water were re-used repeatedly on the same fields.

The District maintains a full-time seven-man drainage department, headed by an engineer and operating three half-yard excavators, a dragline and two backhoes, as well as the tractor-lowbed trailer and other auxiliary equipment necessary to maintain them. In addition, all District personnel devote at least part of their time to this phase of the program.

To encourage the installation of adequate drainage systems, the District provides, at no cost to the landowner, the necessary legal and engineering services, does the leg-work involved in obtaining agreements and rights-of-way where several owners are involved, provides the minor hand-labor required for installation of culverts, flap-gates, and road-crossings, replacing fence, etc., and guides the owners in applying for Federal repayment under conservation provisions where indicated. If desired by the landowners, District excavators and operators are used for the actual construction, the cost of operating them being repaid to the District, with these costs divided among the participating landowners proportionally on the basis of individual acreage drained.

The charge to the owners is based upon $7.00 per operating hour of the excavator, which has averaged out, over the years, to

be just about what it costs to run them and pay the operator, depreciation not being considered. This is from three to five dollars less than the current charge being made by local commercial operators, but no objection has been voiced by them for several reasons. They have all the work they can handle constructing irrigation ditches, which the District does not touch, many of the projects the District takes on would be uneconomical for the commercial operator because of size and location, and finally the District's educational program and engineering services have actually created more work for the commercial operators than existed previously.

The District attempts to assist in solving the drainage problems of anyone in the County who requests such help, while at the same time maintaining a priority list of the major mosquito producers. This practice has kept all of our men and equipment busy installing drain systems twelve months a year with the only time lost being that necessary for maintenance and repairs or moving.

To date it has been unnecessary in Merced County to invoke the legal provisions which may be used in California to force drainage where needed for mosquito control. Probably, however, such action will be necessary in the future to eliminate some of the major sources where owners have shown themselves to be immune to education or persuasion.

An average of approximately 6,000 acres of active mosquito sources have been eliminated or drastically reduced annually in Merced County during the past few years through the direct efforts of the Mosquito Abatement District. It would be difficult to estimate how many more have been reduced through the individual efforts of the landowners influenced by the District's constant educational program or by action taken by the landowner after he has seen the effect of District-installed drainage on his neighbor. The District has no illusions that it will ever be able to drain all of the county's mosquito sources through its own efforts, for the simple reason that more new source-areas are created each year than it can eliminate by direct action. Our ultimate aim is to have installed enough "demonstration" drainage systems, and by other means educated enough of our ranchers so that fewer new sources will be created, and more of the landowners will take the initiative in getting rid of existing mosquito-producing areas in their fields.

In California, with some 7½ million acres currently under irrigation, this is a tremendous problem to be solved, and it will undoubtedly get worse before it gets better, since the area expected ultimately to be under irrigation in the State is 21 million acres. But it is a problem we can view with hope and optimism, because we know that the solution lies in the three factors of better land preparation, improved irrigation practices, and the installation and use of drainage systems and because we are beginning to succeed in passing this knowledge along to the people most affected and best able to apply it, the irrigating ranchers. Such education has a habit of chain-reacting and it is not only our hope, but our belief, that when that ultimate irrigated area is reached, most of the water will be applied to it by people who have learned that mosquitoes are not a necessary by-product of irrigated agriculture, but rather a sign that fields are producing crops below peak efficiency.

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MOSQUITO CONTROL IN RESERVOIRS BY WATER LEVEL MANAGEMENT

GRIGSBY S. CHRISTOPHER [1] AND NICHOLLS W. BOWDEN [2]

Water management, properly employed, is the most potent single measure that can be applied toward controlling mosquito production from a manmade impoundage. Water management for mosquito control means the manipulation of reservoir water levels in such a manner that the microhabitat normally favorable for mosquito production is either destroyed or the mosquitoes are prevented from developing beyond their larval stage. Before attempting to apply the principles of water management for the control of a particular species of mosquito in a particular reservoir, however, it is first necessary that the primary purpose of the reservoir and the water management problems associated with carrying out this primary purpose be clearly understood.

Dams are constructed and reservoirs impounded for any one of a wide variety of reasons. Such reasons might include domestic or industrial water supplies, flood control, irrigation, hydroelectric power, recreation or navigation, to mention only a few. Some reservoirs are termed multi-purpose in that they are constructed and operated to serve two or more principal interests. The particular purpose or purposes to be served by a reservoir dictate within certain limits the general type of water management schedule required to carry out its primary mission.

Water supply or irrigation reservoirs are constructed to store water during periods of high streamflow to assure an ample supply for use throughout the year as needed. The operation of such reservoirs is aimed, in general, toward maintaining the reservoir water level at or as near full pool elevation as possible consistent, of course, with supplying the demand for water. It is usually desirable, with respect to recreational reservoirs also, that near full pool elevations prevail especially during seasons when recreational activities are at their peak. Spilling of excess water is of no particular concern after the full pool elevations have been reached. Spilling at elevations below full pool, however, may at times be most undesirable.

On the other hand, a flood control reservoir requires an opposite type of operation. In order to carry out its designed mission, there must be ample storage space available when needed to collect and hold, at least temporarily, flood flows in excess of that which can be safely passed downstream. Following such a flood control operation, the reservoir must be lowered sufficiently through regulated discharge to place it in readiness again to temporarily store and regulate the next flood. Thus, the operation of a flood control reservoir is toward maintaining a minimum pool elevation rather than a full pool.

Operation of a reservoir designed to serve navigation interests demands that a certain channel depth be maintained at all times. In addition, sufficient water must also be available to operate the navigation locks. Navigation requirements, therefore, necessarily fix the minimum reservoir drawdown elevation. Operation of the reservoir at elevations above this minimum is not of too much concern to navigation as long as excessive flow velocities and too rapid rise and fall in stage are avoided. These latter considerations demand careful regulation of reservoir discharges to prevent swift currents and

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unduly large water level fluctuations downstream from the dam or in certain critical stretches of the reservoir.

Reservoir water management for hydroelectric power generation may at times be more complicated than those operations previously discussed. Theoretically, one acre-foot of water through one foot of head is capable of producing 1.025 kilowatt hours of electricity. Thus power generation depends upon both the volume of water and the head available. The most efficient operation also demands that all available water be passed through the turbines and not over the spillway. Water over the spillway is lost to power generation and also will tend to reduce the effective head at the dam by raising the elevation of the tailwater level. Depending upon many factors too numerous and too complicated to mention here, it may be beneficial from a power standpoint to operate at times over a wider range of reservoir water elevations than is normally planned. In the face of an expected increase in flows, for instance, it may be advantageous to draw heavily on a reservoir through turbine use. The possible loss in efficiency from such an operation which might result from a steadily decreasing head may be more than overcome by the ability to store the impending flows for future use rather than being forced to waste water over the spillway.

Consistent with other influencing factors such as climatic conditions, water temperatures and shoreline topography, the type of reservoir water management followed in any given reservoir will determine the prevalence and type or types of mosquitoes occurring in that reservoir. Mosquito production in a reservoir may be considered, therefore, as an undesirable by-product obtained in the process of operating the water levels of a reservoir to accomplish its primary purpose. But, just as certain water management practices can create biological conditions which favor mosquito propagation, the water itself can also be employed in most instances to limit or completely eliminate such mosquito-producing situations. Water management "tools" such as weekly cyclical fluctuation and seasonal recession have been successfully employed on reservoir mosquito control programs for a number of years. Their effectiveness and economy have been well documented. From the foregoing brief discussion of the several types of reservoirs, however, it should be apparent that each individual reservoir presents specific problems with respect to the application of water management for mosquito control. The degree of effectiveness which can be achieved through such a program on a particular reservoir will depend chiefly on the following factors:

(1) How well the specific water management requirements for mosquito control can be identified in advance.

(2) How closely these requirements can be incorporated into an over-all reservoir water management schedule without materially interfering with or adversely affecting operations necessary in carrying out the primary purpose of the reservoir.

(3) The development of a system of communication whereby the day-to-day water management needs for mosquito control can be made known and can be weighed along with other considerations by those responsible for making decisions concerning management of the reservoir water levels.

Much has been said, written, and published during the past 20 years concerning the use made of water management by the Tennessee Valley Authority in controlling the production of *Anopheles quadrimaculatus* mosquitoes on its system of reservoirs. The manner in which the salient water management features of *A. quadrimaculatus* control are integrated into the over-all TVA reservoir water management plan, however, may not be so widely known or understood.

The TVA plan for the development of the natural resources of the Tennessee River Valley called for the construction of a series of dams to impound the main river from a point near Paducah, Kentucky, to Knoxville, Tennessee, a distance

of some 650 river miles. In addition, reservoirs were also to be constructed on the principal tributary streams. The plan was unique in many respects. The concept of operating a multi-purpose reservoir was relatively new in the early thirties and there was no precedent for operating so large a system of such reservoirs, nine of which would form a continuous chain in the main Tennessee River. The reservoirs were to serve the primary purposes of flood control, navigation, and power. Superimposed upon the water management problems presented by these primary considerations was the need to control malaria transmission in the areas contiguous to these reservoirs. This meant the use of water management to control the production of *A. quadrimaculatus* mosquitoes in the reservoirs.

Eight years elapsed between the impounding of Wheeler, the first main river reservoir constructed by TVA, and Kentucky Reservoir, the last link in the main river chain. These years were spent in identifying the water management needs of each program interest and attempting to reconcile requirements which at first appeared to be somewhat conflicting at times. Recommendations by each program interest were studied by what is now the TVA Division of Water Control Planning in the light of over-all needs and benefits, always giving priority to the main statutory objectives. Temporary schedules of water management operations were set up as each reservoir was completed and impounded. It was often necessary during this period, however, to make departures in the planned management to facilitate construction of the dams. Periodic contacts made in the beginning of TVA reservoir operations were expanded so that by 1942 direct lines of communication between the malaria control staff and the water control planning staff had been established administratively within TVA. This permitted the day-by-day needs of malaria control to be considered along with the needs of the primary programs. Also, the effect on malaria control of any proposed temporary departures from scheduled operations could be discussed. In February 1945, from the experience gained during these construction years, TVA officially adopted the Multiple-Purpose Reservoir Operations water management charts which are still in use today. Each reservoir has its own individual characteristics which are reflected in its operation chart. The chart for Pickwick Reservoir, however, contains the main features which are typical of the water management schedules followed by TVA on its main river reservoirs.

The minimum flat pool level was set by navigation requirements to assure at least a nine-foot navigable channel at all times for river transportation. From studies of rainfall, runoff, flood frequencies and histories, it was determined that major basin wide floods in the Tennessee Valley occur chiefly in the winter and early spring months. Major floods on the main river have been limited almost exclusively to the months of December through April with the highest frequency in March. To provide flood storage space during this potential flood period, Pickwick Reservoir is held from 4 to 6 feet below normal full pool elevation from December to mid-March. Storage space below normal full pool in the other main river reservoirs ranges from a minimum of 2 feet in Guntersville to a maximum of 7.5 feet in Chickamauga. The generation of power is not materially affected by this operation since the effective head at all dams but Kentucky remains approximately the same except during actual flood control operations. The head at Kentucky Dam is 5 feet less since it is lowermost in the reservoir chain. This low water during the winter is helpful to malaria control in that it attenuates the growth of submerged aquatics in the reservoirs. The exact date to begin filling the reservoirs in the spring is determined by present and prospective streamflow conditions with the aid of current weather forecasts and longer range weather outlooks. The ideal time to initiate filling is after the last danger of flood

has passed but before the normal spring rains have appreciably diminished. The decision to begin filling is arrived at by the Division of Water Control Planning primarily on the basis of flood control considerations but with the full knowledge of the adverse effects delayed filling might have on both power and malaria control. Power is interested, of course, in filling the reservoirs while sufficient water is still available so as to have the water for use during the low flow season later in the year. Malaria control desires a full pool before the growing season becomes well advanced to prevent growth of vegetation in the exposed portion of the reservoir basin.

Upon filling to full pool elevation, a flood surcharge is provided. This is a malaria control operation, although some minor benefits to navigation and power may result. The water is raised above full pool, by one foot or more where practicable, and returned rapidly to strand accumulations of drift and flotage upon the reservoir margin above full pool elevation. In effect, this is a mechanical cleaning operation.

The constant pool phase which follows is extremely beneficial to malaria control as a long-range marginal plant growth control operation. Since an ample supply of water is usually available at this time for power generation, this full pool phase of the water management schedule does not adversely affect the power program.

Mosquito production at first occurs sporadically. As production becomes more generalized, weekly fluctuation cycles of about one foot in depth are initiated simultaneously at the request of malaria control on all the main river reservoirs except Kentucky. It takes about ten days to two weeks to set this operation in full motion. It is accomplished through a complex system of shifting power loads so that as one reservoir is being drawn down, the one immediately downstream is filling. As long as no water is spilled in carrying out this operation, cyclical fluctuation does not adversely affect the power program since the average head available at each dam remains essentially the same.

The next step in the TVA water management schedule is water level recession. Recession provides excellent immediate *A. quadrimaculatus* control by continually drawing the water below the marginal band of vegetation and thus maintaining a clean shoreline. Coming as it does in the latter part of the growing season, the chances for further invasion of significant plant growth into the reservoir are lessened. Recession benefits power by making water available for generation without substantial change in effective head during the late summer and fall dry season when river flows are normally lessening. Also, to reach the required flood control elevations by December, recession provides for the use of water previously stored, usually without the necessity of spilling. Malaria control takes advantage of the lower lake levels in the fall to perform shoreline improvement and maintenance operations. Last year the Malaria Control Branch began a joint study with the TVA Division of Power Operations to determine if any net gains to TVA operations could be realized through delayed recession. As a result, recession was delayed on Watts Bar and Fort Loudoun Reservoirs on an experimental basis for two months beyond the present guide curve schedules. The results looked good and the experiment is to be repeated this year. From studies on other reservoirs, however, possible over-all gains from delayed recession do not appear promising.

Last year also, TVA broadened the scope of its mosquito control program to include, in certain limited situations, the control of floodwater mosquitoes. Studies to date indicate that the over-all water level management schedules now in use by TVA are effective in controlling these mosquitoes. It is the occasional necessary deviation from normal operation that may be significant with respect to floodwater mosquito production. The need for special operations does occur from time to time

on any reservoir. Unusually heavy rainfall in June, a barge stranded on a mud bank outside of the channel, bridge construction or emergency repairs at a dam, or other special situations may all require temporary departures from guide curve operations. It is at these times that the close liaison which TVA provides between its water control and mosquito control staffs becomes of utmost importance.

An operations schedule which embodies the needs of all interests together with a system by means of which day-to-day needs may be considered is required to assure the most effective reservoir water management for mosquito control.

LEGAL ASPECTS OF COMPULSORY ELIMINATION OF MOSQUITO BREEDING AREAS

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In this paper, an attempt is made to discuss the subject matter from a national viewpoint. Briefly summarized are pertinent excerpts from selected state laws and some experiences under these laws pertaining to compulsory action. The states selected for this discussion are: California, Utah, Illinois, Ohio, New Jersey, and Virginia.

California. Under the Mosquito Abatement Districts Act in the California Health and Saefty Code, each district mosquito abatement board has authority (a) to take necessary steps to exterminate mosquitoes in or within migrating distance of the district; (b) to abate as public nuisances artificially created mosquito breeding places; (c) to notify a property owner of the existence of a nuisance, hold hearings on the notice, determine thereafter whether abatement must be made, direct him to comply, or abate the nuisance when he fails, and initiate lien action against the property involved to enforce payment. The California law also includes a penalty clause: Any person who retards activities of the district is guilty of a misdemeanor.

It is noteworthy that even though the district boards have been given these unique and strong powers, there have been no instances where mosquito abatement agencies have had to resort to formal court proceedings to eliminate any nuisance. The Mosquito Abatement Act has been used judiciously; the policy has been to invoke legal remedies only for the relatively few people who are completely uncooperative. In a typical case involving a recalcitrant individual, a letter from the District Attorney advises him that the presence of the nuisance is in violation of the Health and Safety Code. He is persuaded to accept responsibility for elimination of the nuisance and for prevention of its recurrence. In the majority of cases, no further action has been required.

Utah. The Utah law states that each board of trustees is authorized (a) to take all necessary steps for the extermination of mosquitoes, and (b) to abate as nuisances mosquito breeding places in or within migrating distance of the district. There is no provision for initiating a lien action, but a penalty clause makes it a misdemeanor for a person to interfere with the board in the exercise of its powers.

According to Dr. Don M. Rees, it has not been necessary for any of the mosquito abatement agenices in Utah to take compulsory legal action with respect to control operations. However, in a few instances during the early part of the program,

police protection was obtained to conduct larvicidal operations on certain properties where the owner objected to the entry of mosquito abatement personnel. In a few cases, the legal department has written letters requesting property owners to make certain improvements or asking them to desist from certain water storage activities. The mandatory compliance or penalty clause (misdemeanor) is usually cited to anyone who objects to the mosquito control operations.

ILLINOIS. Under the Illinois statutes, the board of trustees is authorized (a) to take all necessary steps for the extermination of mosquitoes within the district, and (b) to abate as nuisances mosquito breeding places. No provision is included for a lien action or penalties for violations.

Mr. Charles F. Scheel has stated that none of the districts in Illinois has ever found it necessary to take any legal action.

OHIO. In Ohio the functions of mosquito control are given to sanitary districts. The regulations for the prevention and elimination of mosquito breeding places are drafted, promulgated, and adopted by the board of directors, but in a district lying wholly within one county, as in the case of the Toledo Area Sanitary District, the law provides for only one director. Therefore the regulations which are in effect were adopted by him. These regulations may be enforced in three ways: First, by the district's entering upon the land, after notice to the owner or tenant, and abating the condition violated by the regulation, the expense of such abatement becoming a lien upon the land; second, by an injunctive action filed in court to require the person violating the regulation to comply therewith by court order; and third, by criminal prosecution for failure, after notice, to comply with the regulation, such failure constituting a misdemeanor punishable by fine of not more than $100, each day's non-compliance, after notice, being made a separate offense.

According to P. B. Brockway, Jr., Superintendent of the Toledo Area Sanitary District, as yet it has not been necessary to use compulsory action. The policy of the district has been to bend over backwards in order to obtain full cooperation from a company or an individual in the controlling of mosquitoes and eliminating their breeding sites.

NEW JERSEY. Under the New Jersey statutes, the mosquito commissions have all of the powers of a local board of health insofar as they pertain to a mosquito breeding nuisance (artificially created) except over lands owned by a municipality, county, or the state.

Mr. Daniel M. Jobbins has informed us that there have been a number of situations calling for legal action at the county commission level, and procedures have been well established under the boards of health and mosquito laws. Legal action is the last recourse, and experience with the cooperative approach has been good in all but extreme cases.

Although mosquito commissions have concurrent powers of local boards of health with respect to mosquito abatement, in most cases the county commission proceeds as complainant and witness before the board of health and local magistrates who officiate under their own local and state authority. Strict compliance with the law as to preliminary survey, notice to owner to abate the nuisance, and the pattern defined in the statutes assures favorable outcome of the cases.

In the case of corporate bodies such as railroads, the injunction procedure has been employed with good effect. This consists of filing a bill in the name of the state by the local health board with the State Court of Chancery. The bill prays the court to prohibit the continuance of the mosquito nuisance. Any such action requires caution since costs are chargeable to the loser of the action; consequently, strict compliance with the law and the evidence must be well supported.

VIRGINIA. The Virginia law states that each mosquito control commission is authorized to do anything deemed necessary

for the control and elimination of all species of mosquitoes in the district. There is no provision regarding lien action; neither is there a penalty clause for violations.

Information supplied by Mr. R. E. Dorer indicates that no cases have been brought to court. It has been felt that it is better to educate rather than to prosecute. Usually a notice is all that is needed.

Conclusions. Although specific provisions of the various state laws vary considerably with respect to compulsory mosquito abatement, there seems to be unanimity of opinion regarding (a) the legal basis for mosquito control and (b) the place of the legal approach in abatement activities. These conclusions are summarized below.

1. *Legal responsibility for mosquito control is associated with land ownership or operating rights.* The owner on whose property a health hazard occurs should generally be held responsible for taking necessary corrective action under the laws.

2. *Legal responsibility pertains to man-made situations rather than to "acts-of-God."* In most instances, the individual should not be held personally liable for those acts that are not controllable by man. The California and New Jersey laws are very specific and exclude natural breeding sources in defining a nuisance.

3. *The desirable approach for the control of the problem is by means of education and cooperation rather than by litigation.* In California, remarkable success has been obtained by assisting the farmer in solving his problems. For example, it is the practice of many of the districts to provide the necessary heavy machinery required for source reduction techniques, particularly drainage, at cost to the landowner.

4. *The legal approach should be used as a last resort for the few who will not cooperate.* The legal machinery should be regarded as a "big stick" and used only infrequently, and then only when it is in the public interest to do so.

5. *Legal action should not be taken unless the public opinion is in sympathy with such action.* In general, public opinion will be in sympathy with the district if the district has been in strict compliance with the law and has been considerate of the violator—while the violator, in contrast, has been completely uncooperative and a hindrance.

Is there a Need for New Legislation or a Revision of Existing Laws? The need for new legislation or a revision of existing laws should be based upon the problem in local areas. A specific example is a borrow pit ordinance, which was adopted by the city of Hampton, Virginia, in 1956. This ordinance was adopted to prevent the creation of mosquito breeding areas associated with a multi-million-dollar New Tunnel project. The New Tunnel is a bridge and tunnel combination across Hampton Roads, connecting the Lower Peninsula with the Norfolk area and will replace the ferry service. Since the project would require 3½ million cubic yards of fill material, considerable concern was expressed regarding borrow pits that would be created. The ordinance specifies that the borrow pits must be made self-draining, unless they are established along a navigable stream, in which case free standing water (minimum depth of 2½–3 feet) would be permitted.

In certain instances, if an inventory is taken of existing state laws it may be found that there is little need for new legislation. California may be cited as an example. Reference has already been made to the Mosquito Abatement Districts Act under the Health and Safety Code. Other statutes which can be used for the abatement of water conditions in California include various laws of Health Departments, Flood Control Districts, Agricultural Districts, and Water Conservation Districts.

In closing, we should like to emphasize that existing statutes should be studied to determine if the provisions are *adequate* and *reasonable* under present conditions. The review would indicate if adequate

protection to public health is afforded. It would also indicate if there is a need for modernization of certain sections. Our final suggestion would be that the laws of all states be studied in order to profit from the thinking and experiences of many individuals.

SUMMARY. Briefly summarized are pertinent excerpts from selected state laws and some experiences under these laws pertaining to compulsory action. It is concluded that: (1) Legal responsibility for mosquito control is associated with land ownership or operating rights, (2) legal responsibility pertains to man-made situations rather than to "acts-of-God," (3) the desirable approach for the control of the problem is by means of education and cooperation rather than by litigation, (4) the legal approach should be used as a last resort for the few who will not cooperate, and (5) legal action should not be taken unless the public opinion is in sympathy with such action. The need for new legislation or a revision of existing laws should be studied to determine if the provisions are adequate and reasonable under present conditions.

ACKNOWLEDGMENT. The writer is deeply indebted to the following persons for assistance in the preparation of this paper: Mr. B. F. Keefe, Mr. P. B. Brockway, Jr., Mr. R. E. Dorer, Mr. W. H. Huneycutt, Mr. D. M. Jobbins, Mr. G. C. McFarland, Dr. D. M. Rees, and Mr. C. F. Scheel.

A DECADE OF MOSQUITO SOURCE REDUCTION IN A LOCAL MOSQUITO ABATEMENT DISTRICT PROGRAM

ROBERT H. PETERS
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The Trustees of the Northern San Joaquin County Mosquito Abatement District initiated a sound program of mosquito source reduction at the start of the agency's operations in 1945, when the district was formed. It was recognized that only through a progressive reduction of the mosquito sources, could a desirable degree of control be accomplished, within economic limits, in this area of the central valley of California.

Surveys of the main control problems, by the first manager of the District, Mr. Ernest Campbell, indicated that the jungle-covered riverbottom of the Mokelumne River, which produced three *Aedes* species, *A. vexans, A. increpitus,* and *A. stictícus,* was the foremost problem; followed secondly by the irrigated pastures (both improved and unimproved) which produced *Aedes nigromaculis* and *A. melanimon* as well as *Culex tarsalis;* and thirdly, the various organic ponds associated with our grape and wine industry, in which three *Culex* species, *C. stigmatosoma, C. tarsalis* and *C. pipiens* were found in abundance. The vast majority of these organic ponds were also located along the Mokelumne riverbottom, and in most cases the outflows poured into the jungle-covered lowlands adjacent to the river.

In addition, the problems of irrigation on other crops—rice fields, duck clubs, and the usual domestic sources—contributed their share to the total of seventeen species of mosquitoes found in the 409 square miles of our District. Needless to say, the myriads of mosquitoes pretty well dictated the limits of human activity prior to the start of our control operations, and now—after a decade of effort—it is inter-

esting to evaluate the effect of applied mosquito source reduction over this period of time.

For all intents and purposes, our source reduction program began around the first of the year in 1946, and since that time we have utilized the following units of heavy equipment and tools to accomplish our objectives:

2—D-7 Cat. Tractors equipped with 13½' dozers
2—12 yd. Carryall Scrapers
1—P. & H. Dragline, ⅜ yd.
1—Ferguson tractor equipped with blade and mower
1—Pull grader
2—Ditchers
1—Transit level
24—#2 shovels

Our personnel in this division consists of two full-time heavy-equipment operators and such part-time assistants as are required for maintenance or shovel work from time to time. Most of the public relations work, surveying, and arranging have been done by the manager, and recently, a source reduction inspector.

Perhaps I should point out that most of our accomplishments have been realized through what we refer to as our cooperative program, which has been supported almost entirely from funds derived in payment for work done in accomplishing our objectives of mosquito source reduction while at the same time reclaiming land, or changing mosquito producing areas into usable land or water areas.

The philosophy which has been applied in our approach to mosquito source reduction is based primarily on the fact that there appears to be an economic justification which can absorb the cost of eliminating or reducing the areas where mosquitoes breed; secondly, that it is important to follow a complete plan of determining and recommending an effective solution of the problem to the responsible party or landowner; and finally, that only by supplying the necessary equipment, tools and know-how can we effectively accomplish our desired objective at the lowest possible cost. This is done by renting our equipment, along with operators and manpower, on a cost basis, which usually runs about one-half of commercial rates.

After more than a decade of applied mosquito source reduction, it is interesting to note that some rather sweeping and elaborate statements can be made and justified; such as, "Our tax rate is now lower than when our program started, in spite of the decreased value of the dollar." "Our insecticide costs along the Mokelumne bottomlands in recent years are only about one-seventh of previous years." "It is now difficult to collect specimens of our riverbottom mosquitoes." "One 300-acre pasture which averaged $500.00 per year in control costs did not have to be sprayed during the year of 1956." "Re-circulation systems planned and constructed by our Agency have reduced control costs on a number of pastures to only a fraction of previous amounts expended."

Just what these statements mean in terms of work accomplished can probably best be shown in the following quantitative summary of this program over the past decade:

No. of projects worked on	83
Area of land cleared and/or rough leveled	1,150 acres
Levees constructed or rebuilt	7½ miles (approx.)
Drainage ditches constructed or maintained	15½ miles (approx.)
Water storage ponds constructed or rebuilt	20
Acres of water storage ponds	105
Heavy equipment machine hours (total)	22,850

The scope of our source reduction activities has been broad and varied with projects resulting in everything from opening areas to agriculture; building levees; constructing ponds for sewage disposal, grape and cannery wastes; designing re-circulation systems for pastures; drainage sys-

tems; also assisting in the re-shaping and construction of recreation areas and small aquatic parks.

Our only requirement for participation in such activities is that an actual or potential mosquito problem must be involved to justify our assumption of the work aspects of a project. To this end we have successfully accomplished this program without measurable opposition from private enterprise in the heavy equipment field.

Although our agricultural source reduction program has only just begun we have, to date, eliminated or greatly reduced about three-fourths of our natural type sources located mainly along the Mokelumne riverbottom. This is particularly significant since California law places the responsibility on the control agency to assume the burden of mosquito control in natural locations, while the individual is responsible for artificial or man-made sources of mosquitoes. We have, in effect, through this cooperative program changed many sources from natural to artificial and for the most part without any cost to the taxpayers of our area—thereby, according to our law, actually reducing our total problem and switching the future legal responsibility to the individual owner in the same process.

With the ever-increasing expansion of irrigation and water use in California, there is no doubt in our minds that our applied mosquito source reduction program has been extremely effective in meeting this challenge, as well as in coping successfully with the insecticide resistance problem.

Our State Health Officer, at our recent California Mosquito Control Association Conference, terminated his talk by reminding us—through re-phrasing a "commercial"—that in California mosquito control, "progress is our most important product." It might also follow, to add a rephrased quote from another national "commercial": that "you can be *sure* if your program is based on *source reduction.*"

VEHICLES FOR THE TRANSPORTATION OF INSECTICIDES

P. BRUCE BROCKWAY, JR.
Toledo Area Sanitary District

It is relatively easy for the newer mosquito control districts to improve their control methods. This is especially true with the Toledo Area Sanitary District. During the past couple of years we have been investigating various improvements to vehicles which transport insecticides. The air boat and swamp buggy were the pieces of equipment under consideration.

AIR BOAT. Due to the fact that we have an extensive mosquito control problem on marginal shallows of the Maumee Bay and Maumee River areas, we purchased an air boat (Fig. 1) in the spring of 1956. This purchase was made after due study of other shallow draft hulls such as the water jet-propelled and various underwater propelled craft. Of course, the idea of the air boat is not new. I am sure that most of you have at least seen this type of craft in action. However, we found that one of our local boat builders, Ray Greene & Co., was entering into contract with the U. S. Navy for a rescue hull of similar design, made of fiberglass and plastic. The hull was 18 ft. 7 in. long and 8 ft. 4 in. wide, and had a depth of 22½ in. It was a sealed hull with

three inner-sealed compartments and reinforced decking. Steel plates had been securely anchored at various places in the hull and these were used for motor mounts, blocks and cleats. Upon delivery of our boat, our mechanics immediately began building a motor mount for a previously purchased Lycoming 190-HP engine. The engine was placed so that the propeller would not be a hazard and at the same time we would have traction propelled action or a pusher type motion. Numerous other pieces of supporting equipment, such as a trailer, ramp and boat house, were readied for a busy summer season.

By mid-May, just before the *Culex pipiens* started activity, our air boat was in use and ready for action. Of course, before we started any mosquito control activities in these marsh problem areas, the boat crews made paths through the cattails with the air boat and these were used as avenues for larviciding application. The boat crew became skilled in the use of this equipment and learned where and under what conditions it could best be used. Such problems as cattails hitting the propeller and damaging it were encountered but as the paths were worked wider and longer this difficulty was overcome. The hull was very satisfactory; it withstood all the bumping and scraping that it was subjected to this year with negligible damage.

No problem developed by condensation or leakage into the sealed hull. The hull does not require painting or caulking. However, a coat of anti-fouling paint may be useful. Mr. Ray Greene has stated that if a patch is necessary due to a break in the bottom of the hull, this patch may be applied easily and quickly by the operating crew. The average wooden or

Fig. 1.—Air boat in action.

aluminum hull could not have withstood the terrific beating that the fiberglass took with so little damage.

As far as turning radius and other boat maneuvering questions, this equipment showed quick response to the wheel at high speeds but, of course, this was not as pronounced at lower speeds unless the engine was speeded up. The only maneuver that the standard air boat cannot perform is backing.

The question of speed always comes up and we answer it this way: We have been clocked on a known water racing course at more than 25 MPH. However, our operators are instructed not to exceed the Toledo Harbor rate of 10 MPH. In spite of the fact that the hull and engine and supporting equipment weigh approximately one ton, the boat draws only about 6 inches of water at the transom when it is not in motion. When traveling at the average speed the boat draws about three or four inches.

The air boat will operate very well with one-half inch or so of water over the marshlands and, like other air boats, will cross sand bars and mud flats provided enough speed and momentum has been developed. Of course, draft at the fantail depends largely on the placement of the movable weight, such as spraying equipment. Therefore, generally speaking, the boat only draws four inches of water at the deepest point.

This equipment has solved a number of our larviciding problems and we will continue to operate it during the coming years.

MARSH BUGGY. It has long been the opinion of the writer that there is a need for a reasonably priced 4-wheel-drive swamp buggy. This is not a new idea because there have been many innovations of this type of vehicle over the past thirty or more years. At the Toledo Area Sanitary District we decided to use the Willys 1-ton 4-WD because it was one of the most common vehicles used in mosquito control, plus the fact that it is reasonable in price. The Willys Motors, Inc., loaned this District a standard 1955 Willys 1-ton truck for the purpose of experimenting along this line.

Our mechanics stripped the fenders and bed off this vehicle (Fig. 2) and then welded the spring saddles on top of the front and rear axles and also inserted a short extension on the front wheel drive shaft, this being necessary to take up the difference caused by raising the body.

Of course, there were a few other minor changes such as the longer hydraulic brake lines and the placing of the Pittman arm on top of the front wheel assembly rather than under as it is on the standard vehicle.

We were able to obtain some 12:50x16 aircraft tires and tubes which we mounted on Chevrolet truck rims that were cut and welded on the Willys wheel hub. By doing this, we extended the tire center from the standard 56" to 74".

We have used this vehicle for two full years and consider the experiment well worthwhile in spite of the fact that some of the Willys engineers scratched their heads and doubted that it would be a success. In the fall of 1956 we added the new Spicer free-floating-drive axle on the rear wheels, which gives drive on each of the wheels regardless of whether one wheel is stuck or not.

The tires cost $25.00 each because they were factory rejects and the rims and their extensions came to about $25.00 per wheel, which includes milling and welding, making a total cost of approximately $250.00 for turning the standard Willys 1-ton truck into a marsh buggy.

This unit seems to go where even angels fear to tread and it seldom becomes bogged or stuck, and even when it does get stuck it can be pushed out by hand. The usefulness of this vehicle is almost limitless because it is so mobile and its ground pressure is so low. It can travel at the rate of 30 to 40 miles an hour on hard surface road, yet it can go as slow as desired over marsh terrain. Generally speaking, the District has used this vehicle in its prehatch dusting program with a Root

duster applying 50-W DDT. However, a 50-gallon tank and pressure sprayer can easily be substituted for use around extensive marsh or field larviciding programs.

One of the main problems in mosquito control is tire rut mosquito breeding and this sometimes is caused by a mosquito control district's own vehicle making the ruts. The TASD swamp buggy will of course make ruts; however, where the conventional 1-ton 4-WD Willys truck will leave a 2-inch rut, the swamp buggy will leave only a slight indentation on the wet ground.

We no longer consider the Willys swamp buggy as an experiment; it has now joined our fleet of working vehicles and it is proving its value.

Fig. 2.—Swamp Buggy.

Have you indicated which tours you wish to take on February 25 in Washington? See page 319 for further information and instructions.

A NEW WHEEL-MOUNTED INSECTICIDE MIST SPRAYER

CARL WESLEY, JR. AND RICHARD P. SCHMITT
Engineer Research and Development Laboratories, Fort Belvoir, Virginia

For a number of years Preventive Medicine Units and Engineer Insect and Rodent Control personnel in the military service have had a need for a portable or lightweight, insecticide mist sprayer that could be used both inside buildings for space and residual spraying and outside for residual spraying and adult insect control.

In 1950, Mr. Husman of the Orlando, Florida Laboratory of the U. S. Department of Agriculture developed a lightweight sprayer which used compressed air with the insecticide pumped at low pressure to generate a mist spray. Several sprayers similar in design were used by the Army in Korea in 1951. This field service and the work reported by the Department of Agriculture provided basic criteria and data for the design and development of a new mist sprayer. Laboratory studies were conducted and several experimental models tested before a suitable design was obtained. It is the purpose of this paper to describe this final design and briefly to discuss its performance.

The sprayer, Figure 1, consists essentially of a gasoline engine, air compressor, insecticide pump and an insecticide tank all mounted on a common base which in turn is mounted on a two-wheel push-cart chassis. As a wheel-mounted sprayer the unit may be pushed by hand into or through areas to be treated. In areas too large for this technique or over terrain too difficult for push-cart movement, the sprayer is readily removed from the wheeled chassis and can be carried in a vehicle such as a jeep or light truck. As base mounted equipment it weighs 140 lbs., and when mounted on its wheeled chassis it weighs 210 lbs. including 5 gallons of insecticide spray.

A gasoline engine is the power source for the unit. It is a typical 2 h.p. general purpose air cooled engine that is available throughout the military supply system. This is an important factor because it is the one component which may require frequent maintenance by replacement of spare parts or complete replacement of the engine. The availability of the engines and spare parts extends the operating life of this sprayer in the field. The engine has a manual throttle control for operation at speeds varying from 2,600 to 3,600 rpm and automatic governor control of a plus or minus 5 percent. An arrangement of belts and sheaves transmits engine rotary power to the air compressor and pump. To facilitate starting the engine, a centrifugal type clutch disengages the belt drives of both the compressor and pump. The air compressor is a heavy duty type of rotary design that gives a non-pulsating delivery of 8.3 cfm of air at a positive pressure of 30 psi when operating at a speed of 1,800 rpm. The insecticide pump is a helical rotary gear type of hardened steel with integral pressure relief valve and pressure fitting. It has a capacity of 1.5 to 4.5 gpm at zero psi and a speed range of from 600 to 1,725 rpm. The normal engine speed is 3,600 rpm. which gives an air compressor speed of 1,800 rpm and insecticide pump speed of 1,500 rpm. The insecticide tank is a regulation oval 5 gallon GI can. The insecticide and air are pumped through separate rubber hose to a wand and sprayhead assembly. The sprayhead consists of 4 combination air-liquid nozzles where compressed air is mixed with the insecticide to break it up into a mist. Both feed lines are equipped with valves that permit manual flow control of either the air or insecticide supply. The nature of the mist (whether heavy or light) is thus controlled by adjustment of the liquid and air valves.

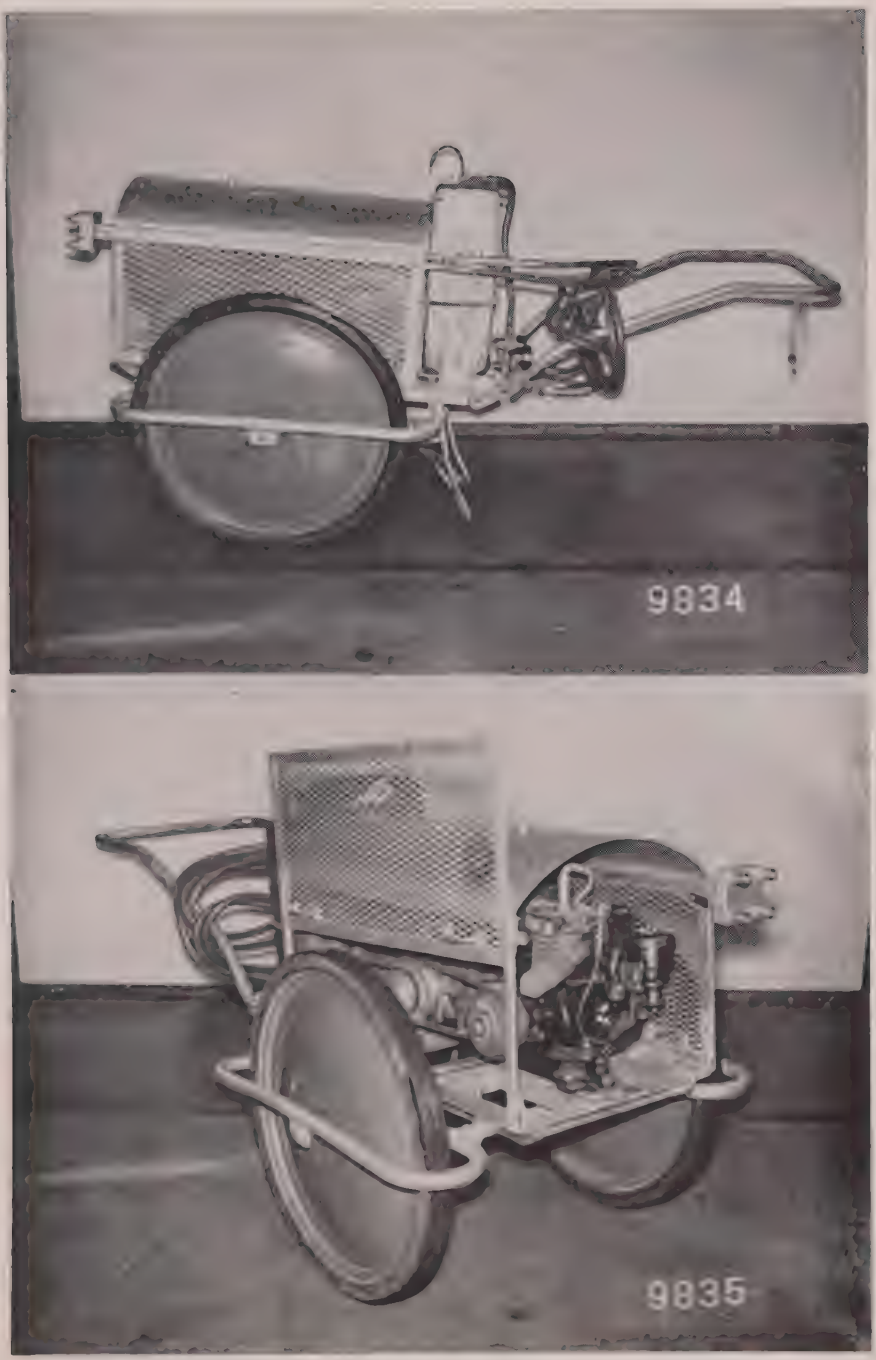

Fig. 1.—Final model of sprayer.

The insecticide line in the wand handle is also provided with a hand operated trigger valve for complete stoppage of the spray by the operator.

By keeping the air pressure constant and adjusting the quantity of liquid pumped, the characteristics of the spray are controlled. By opening the liquid valve or increasing the quantity of insecticide a heavy mist with large particles is obtained; conversely, by closing the valve or decreasing the liquid flow, a light mist is produced. For example, with the air pressure constant at 25 psi and a change in the liquid from 30 gph to 25 gph the mass median diameter of the spray particles decreased from 48 microns to 28 microns.

Combination air-liquid nozzles of various sizes were used in the spray head to find nozzles which would produce spray particles between 30 and 60 microns in diameter and preferably with a mean diameter of approximately 50 microns when using 5 percent DDT in kerosene. Magnesium or dryfilm coated microscope slides were located at intervals of 50, 100, and 150 feet downwind from the sprayer to collect the insecticide particles that would impinge on the slides. The slides were examined under a microscope with an eyepiece micrometer and the sizes of the insecticide particles determined. At 50 feet the median diameter was 55 microns; at 100 feet it dropped to 50 microns, and at 150 feet it dropped to 45 microns. An average of the three distances shows that the median diameter is 50 microns and that 72 percent of all the particles fall within the range between 30 and 60 microns.

Other tests were conducted to determine the amounts of DDT deposited at 50, 100, 150, and 200 feet from the machine. Six-inch glass plates were placed at these distances and chemical analyses of the DDT collected on them were made after they had been exposed to the spray. The amount of DDT deposited varied inversely with the distance of the collecting point from the machine. For example, analyses showed 1.6 pounds per acre at 50 feet and 0.2 pound per acre at 200 feet. The effects of the DDT on mosquito larvae were also determined by bioassay tests. Sterile petri dishes later filled with distilled water and a small quantity of ground dog food were exposed at the same distances from the sprayer. Active fourth instar larvae of either *Culex quinquefasciatus* or *Aedes aegypti* were placed in the dishes and examined 24 and 48 hours later to determine their mortality. Controls were run concurrently in the laboratory by placing larvae, dog food, and water in unexposed petri dishes. Mortalities varied from 100 percent at 50 feet and 20 percent at 200 feet in 24 hours, to 100 percent at 50 feet and 80 percent at 200 feet in 48 hours.

To improve the versatility of the sprayer for field use several accessories were added to permit dispersal of insecticide dust and indoor liquid residual spraying. A standard dusting gun developed by the Quartermaster Corps for use with a personnel delousing unit was adapted for quick connection to the compressed air line of the unit. Also a spray bottle assembly consisting of a one-quart plastic bottle, nozzles, and trigger valve was developed for similar connection. This small hand-operated spraying attachment is used in small restricted places in mess halls and kitchens the same as the dust gun for fly, roach, and ant control. A manifold installed on the compressed air line of the sprayer permits connection of either the dust gun or the spray bottle. Sufficient hose is provided to permit leaving the sprayer with its gasoline engine operating outside the building while the accessories are used on the inside.

Ten working models of this sprayer were shipped to test agencies of the Army Corps of Engineers, Army Medical Service, Navy Preventive Medical Units, Navy Bureau of Yards and Docks and the U. S. Department of Agriculture for operation and field evaluation. With the exception of the units in Korea and France, each agency was visited by a member of the Sanitary Engineering Branch of the Engi-

neer Research and Development Laboratories while the field tests were being made and the performance of each machine was observed. Personnel performing tests on the sprayer consisted of army, navy, and civilian engineers and entomologists who were experienced with insect and rodent control programs both in the field and at permanent installations. While the entomologist was primarily interested in what percentage kill he could get at various distances from the machine with different pounds per acre of insecticide, the engineer was more interested in the operation of the machine and the sizes of insecticide particles it produced. It was felt therefore that the two complemented each other in their work.

The real test of insecticide dispersal equipment is its efficacy in insect control operations. In June 1954, at Fort Churchill, Canada, the sprayer was used for control measures at the Engineer Test Team Camp. Good control was accomplished by space and residual spraying of 5 percent DDT in kerosene both inside and outside of buildings at the camp maintaining a zero landing count of mosquitoes. There was a very dense mosquito population away from the camp in the tundra, where landing counts of approximately 165 mosquitoes per minute on a person's back were recorded. A single spray application of 5 percent DDT in kerosene over a five acre plot of this tundra produced zero landing counts for three days until mosquitoes from the outside area gradually were blown back into the treated area.

The field reports confirmed established requirements for this type equipment, and standardization of the test item with minor modifications was recommended. The sprayer is described by Corps of Engineers drawings and a military specification. These documents cover one complete sprayer and the spray bottle assembly, so that regardless of manufacture they should be similar in design and operating procedure.

Besides being useful to Preventive Medicine Companies, Medical Service Organizations, and Post Engineer personnel in normal insect control operations, the sprayer is also of use in a civilian capacity because of its dual purpose of adult insect control and residual application. It can be used for quick knock-down of flying insects at open air theatres and other such gatherings as well as around dairy barns, stockyards, garbage dumps, sewage plants and summer camps. It is concluded that the sprayer is suitable for classification as standard type equipment for use by all segments of the Department of Defense.

THE NAVY'S DEVELOPMENT OF INSECTICIDE DISPERSAL EQUIPMENT FOR HELICOPTERS

WILLIAM S. MURRAY
Entomologist, Fifth Naval District

The purpose of this paper is to acquaint you with the Navy's development of insecticide dispersal equipment for helicopters. The Navy needs a fast and efficient method of insecticide dispersal for personnel stationed at bases and outposts throughout the world where vector-borne diseases are an ever present threat. A recent malaria outbreak in Port Lyautey exemplified this need.

Aircraft continue to meet basic operational requirements, but slow, powerful models, such as the Stearman trainer are no longer being made. Instead, there are

three general types of smaller military aircraft produced in quantity; light reconnaissance-type planes, jets, and helicopters. Reconnaissance-type aircraft have a limited payload. Jets are much too fast. Helicopters, however, are well adapted for insect control by virture of their maneuverability and capacity to hover. Wider use of helicopters by the services has brought about a reduction of maintenance costs. Payloads are being increased. One relatively new model, the Sikorsky HR_2S, carries a 4,000 pound payload. Therefore, at the present rate of achievement, it appears that increased capacity and versatility can be expected.

The basic research toward the development of dispersal equipment is being conducted in the Fifth Naval District at the U. S. Naval Medical Research Laboratory, Camp Lejeune, North Carolina, under the immediate direction of Cdr. G. S. Stains, MSC, USN. Cooperation in the use of helicopters is obtained from the Marine Corps Air Facility, New River, North Carolina.

The goal of the research is the development of lightweight, spray and granular insecticide dispersal equipment. System components are to be made essentially of standard stock parts, and are to be adjustable to fit any of the larger military helicopters. The spray apparatus will consist initially of two well-braced 15-foot aluminum spray booms, one on either side of the fuselage. Fifty Spraying Systems size 12 cone nozzles, with self-contained check valves, will be evenly spaced along the booms. Fifty-five-gallon drums will contain the spray material inside the aircraft and will be secured by special quick-releasing brackets. Valves and pumps will be installed in the line so as to be readily accessible.

The goal of a 400-foot effective swath width with a maximum spray expenditure of only two quarts per acre has been established to effect maximum relative payload.

Granular materials are to be dispersed from a hopper below which twin rotating impellers will be mounted, one on either side of the helicopter. A prototype impeller has been constructed and will soon undergo extensive testing.

One hundred feet has been tentatively set as the minimum acceptable swath width for granular insecticides. Helicopters will disperse the material at 50- to 100-foot elevations during particle distribution tests.

There are a variety of interesting but perplexing problems that must be investigated before the final equipment will be perfected. Some problems arise in attempting to construct all-purpose equipment of minimum size and weight which will effectively handle both liquid and granular insecticides. Other problems originate from the unusual construction of helicopters. For example, helicopter rotor heads may be single or double; when double, they are either closely or widely separated. Rotor heads are horizontal or, in the case of the tail rotor, vertical. Research data on conventional aircraft concerning swath width, spray spectrum, foliage penetration, and other similar factors, will have to be re-evaluated for modern military helicopters.

To illustrate, conventional aircraft depend partly upon oncoming air pressures to reduce nozzle output to fine droplets. Slow moving, or hovering, helicopters will have to compensate for the loss of such air pressures by the maintenance of greater pump pressure through more numerous nozzles of smaller orifice size. Exactly how many nozzles, their spacing, the direction of their facing and the positioning of the spray booms in relation to the rotor downdraft will comprise much of the basic research.

Granular insecticides require specialized equipment for uniform particle distribution. Among those granular materials used as carriers for insecticides there are common clays, highly absorptive clays, vermiculite, perlite, and tobacco by-products.

The larger, porous, more absorptive granules represent less carrier weight, and

thus an increase in relative payload. However, these larger, lighter particles are readily affected by wind resistance upon ejection from the impeller, limiting desirable swath width. Most granules in this group give up their insecticide rather soon upon immersion.

By comparison, the smaller, dense, less absorptive granules represent less payload, but maintain their momentum longer when ejected from the impeller, thus effecting wider and more uniform swath widths. Most of the denser granules yield their insecticide slowly over a period of time upon immersion which is advantageous in larval mosquito control.

Exceeding the limit of absorption with any of the granules may produce a non-free flowing product which further complicates dispersal equipment problems.

In concluding, I shall refer to a newspaper article which indicates the versatility and potentialities of the helicopter in various roles. The article reports a recent demonstration to top-ranking Navy officials of a remote controlled Kaman HTK helicopter equipped with electronic brain. The last paragraph states:

"Not the least feature of the experimental plane is its potential for ground reconnaissance. The forward part of the plane is equipped with a very small television camera which transmits a conventional TV image to the ground control station. This also permits the operator to control the plane when it is out of his line of sight."

As a result of military research and development, a remote controlled helicopter for inspection and control operations may eventually be part of your mosquito control equipment. One of the Navy's current objectives is the development of insecticide dispersal equipment for that helicopter.

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STUDIES ON *CULICOIDES FURENS* (POEY) AT VERO BEACH

W. L. BIDLINGMAYER
Florida State Board of Health, Entomological Research Center

LARVAL COLLECTION TECHNIQUE. Salt and Hollick (1944) described a method of separating Elateridae from the soil using a concentrated $MgSO_4$ solution. This was first adapted to recovering sand fly larvae by Cameron (1948) in Scotland. R. L. Goulding and co-workers developed a somewhat similar technique during the existence of the Co-operative Sand Fly Research Unit at North Miami, Florida, that has not yet, apparently, been published. As this technique was extensively used by this Unit, it is described briefly below.

The field sample was placed in a topless one-quart oil can so that the can was nearly filled. It was then flooded, thoroughly stirred to eliminate water and air pockets, and allowed to stand overnight. During the night most of the larvae will make their way to the surface of the soil. The water and the top 1½ inches of the sample were then washed through a coarse (8 to 14 mesh) screen and then through a 100-mesh screen. The material remaining on the 100-mesh screen was placed in a small six-inch dish and flooded with a saturated $MgSO_4$ solution. Because of the high specific gravity of the solution, many of the larvae may be seen swimming on the surface of the liquid, where they can be removed with a pipette. After all visible larvae have been removed, the material is stirred and re-examined until three consecutive negatives occur. If no larvae were found upon the first examination, six consecutive negatives would be required in order to record the sample as negative. According to the unpublished reports of the Co-operative Sand fly Research Unit, two men could handle from 200 to 300 samples daily.

This technique was used as a standard for comparison as other techniques were investigated, although a comparable speed in processing the samples was never attained at this laboratory. The most time-consuming part of the technique was that of examining the salt solution for and removing the larvae.

It was thought, since most of the larvae concentrate in the surface layer of the soil after the sample has been allowed to stand, that perhaps they would enter other materials that might be placed above the field sample. One of the materials tried was "Diluex A," a fuller's earth commonly used as a diluent for insecticides. A 1½ inch layer of a soft consistency was poured into the container on top of the sample and flooded. The next day the "Diluex A" was scooped out and washed through a 140-mesh screen. The screen was then inverted and the residue washed into a black photographic developing tray, about 12 inches by 10 inches by 2 inches deep. The whitish larvae are easily seen as they swim across the dark bottom of the tray. They were removed with a rubber siphon hose which had a glass capillary tube at the upper end to reduce the flow of water.

Usually, the tray would contain very little sediment, most of it coming from the inside of the can which had become soiled at the time the field sample was collected. Some field samples will contain annelids, fiddler crabs or other crustaceans and these will sometimes carry a certain amount of marsh soil with them as they also burrow upward to the surface.

As the "Diluex A" had to be mixed with water before using it, ordinary builders' sand, such as is used for masonry work, was substituted. About 2 inches of dry sand was poured into the container on top of the field sample and flooded with water. The following day the sand was removed, placed in a dishpan and washed, the wash-water being poured through the 140-mesh screen. The residue

on the screen is then washed into the black tray and the larvae removed.

The three techniques were compared by placing a known number of larvae in marsh soil in the bottom of a can and attempting to recover them. A series of replicates showed the salt technique to recover an average of 74 percent of the larvae, the sand 70 percent and the "Diluex A" 67 percent. To process samples containing 100 larvae, took from 10 to 12 minutes each, using either the sand or "Diluex A" techniques. The salt method would take about twice as long. At present, the use of building sand appears to be the most rapid and convenient, and will be used in the future for processing field samples .

Results from Collecting Field Samples. Field samples have been collected for one year to become familiar with the distribution of sand fly larvae in the local salt-marshes. Samples were taken along the edges of ditches and ponds and also along transects across the surface of the marsh. Samples taken from along shorelines contained, on the average, more than 10 times as many larvae as those taken on transects which extended across *Batis* and *Avicennia* areas. Moreover, when larvae were found along the transects, they would disappear with the next drought, although they would sometimes reappear when the marsh was reflooded. It has not been determined what becomes of these larvae as the marsh dries: larvae have been found as deep as 24 inches, but crab-holes may provide the means of descent. When holes were dug to a depth of 24" into the dry marsh and sealed, sand fly larvae were found in the bottom of some of the holes three weeks later.

The largest numbers of larvae per sample were found along the larger drainage ditches. Because of their depth, these ditches fluctuated daily with the tide, and the larvae prefer the zone between the high and low tide marks. The soil in this zone is usually covered with a layer of sediment that remains soft and wet, as it is not exposed to the air sufficiently to become compacted. These ditches are usually shaded for most of their length by mangroves, and as a rule, more larvae can be found in the shady sections. One ditch, which had a very low larval population, was fully exposed to the sun, but the erection of artificial shade at intervals along its banks did not increase the numbers of sand fly larvae.

The field-collected samples were also grouped according to soil type. The soils were merely classified as peat, sand, clay, and mixtures of these. Clay soils appear to be least suitable for sand fly larvae, probably because of their compactness. Clay samples had the lowest average number of larvae per sample and the largest proportion of negative samples. Other types of soil and their mixtures were about equally suitable when comparisons of the average number of larvae per sample were made. There was no indication that organic soils were favored.

Samples of sandy soils were surprisingly productive, with a smaller percentage of negative samples than any other. These sands were not the wave-washed beach sands which may be found scattered along the Indian River. The samples were collected along drainage ditches traversing the upland part of the marsh, and the sandy soil contained a considerable admixture of fine silt.

Emergence and Pupation in the Laboratory. Some observations were made upon the emergence and pupation of sand flies in the laboratory. "Diluex A" is a cream-colored clay-like material that was frequently used in these studies as a substrate for sand fly larvae. The larvae were observed to pupate above the water-line where the dark pupal cases were easily seen embedded in the surface of the clay. When these pupae were flooded, they would free themselves from the bottom after a number of hours, and float to the surface. Emergence would then continue successfully.

Two groups of mature larvae were placed in jars and fed with brewers' yeast and a commercial dried tropical fish food. The jars of one group were tilted so that the substrate was partially exposed above

the water level. The other group was kept flooded beneath about ½ inch of water. This test was replicated three times, but no emergence occurred in the flooded jars while the emergence rate in the tilted jars was 70 percent. Larvae in the flooded jar were observed to leave the soil occasionally and swim around the surface.

In another series, mature larvae were placed in jars of water containing 6 to 8 pencil-sized *Batis* twigs. The larvae in the jars would make their way above the water-line and pupate in crevices in the bark. The emergence rate for these jars was 71 percent.

It appears that the larvae of *C. furens* must be above the water in order to pupate, although emergence is not affected if flooding occurs after pupation has been completed.

SUMMARY. New techniques were tested to improve existing methods of collecting sand fly larvae. The results of larval sampling in the field are reported, as well as some laboratory observations on pupation.

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KEYS TO THE GENERA OF LARVAE AND ADULT MOSQUITOES OF THE UNITED STATES [1]

E. L. PEYTON [2] AND S. O. HILL [3]

The collection of *Haemagogus equinus* Theobald in the lower Rio Grande valley near Brownsville, Texas, by Trapido and Galindo in 1955 (1) increased the number of recognized genera of mosquitoes in the United States from eleven to twelve. The addition of this genus to the mosquito fauna of the United States created a problem in taxonomy in that identification keys have not been available in the literature for separating the genus *Haemagogus* from the other United States genera. The Entomology Department of the Fourth U. S. Army Medical Laboratory, Fort Sam Houston, Texas, is responsible for the identification of arthropods of medical importance within the jurisdiction of the Fourth Army which comprises five southwestern states (Texas, New Mexico, Oklahoma, Arkansas, Louisiana). Keys to the genera of larvae and adult mosquitoes of the United States were prepared to include the genus *Haemagogus,* for use by military personnel within the Fourth Army area. It is presented here for interested personnel who are engaged in the identification of mosquitoes.

H. equinus is a tree-hole breeder, and its present known range extends from the Rio Grande valley of Texas south to Colombia (1). The adult is easily separated from other U. S. genera by the bright

[1] Published under the auspices of the Surgeon General, U. S. Army, who does not necessarily assume responsibility for the opinions expressed in this paper.

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Adults (Female)

1. Proboscis stout on basal half, apical half tapered and strongly curved downward; large species, with broad scales of metallic luster on head, thorax, abdomen, and legs....TOXORHYNCHITES
   Proboscis slender, of nearly uniform thickness, never strongly curved downward on apical half. 2
2. Scutellum evenly rounded on posterior margin; palpi of female nearly as long as proboscis; abdomen bare of scales or only sparsely scaled.....ANOPHELES
   Scutellum trilobed on posterior margin; palpi of female less than one-half the length of proboscis; abdomen densely scaled..... 3
3. Wing vein-6 ending at the bifurcation of vein-5.....URANOTAENIA
   Wing vein-6 ending well beyond the bifurcation of vein-5..... 4
4. Spiracular bristles present..... 5
   Spiracular bristles absent..... 7
5. Postnotum with a tuft of setae; squamae without a fringe of hairs.....WYEOMYIA
   Postnotum bare; squamae with a fringe of hairs..... 6
6. Postspiracular bristles present; tip of abdomen pointed.....PSOROPHORA
   Postspiracular bristles absent; tip of abdomen blunt.....CULISETA
7. Anterior pronotal lobes large, almost joining dorsally, collar like; abdominal scales bright metallic violet and silver.....HAEMAGOGUS
   Anterior pronotal lobes small, widely separated dorsally; abdomen without bright metallic scales. 8
8. Postspiracular bristles present..... 9
   Postspiracular bristles absent..... 10
9. Wing scales very broad; tip of abdomen blunt (in part).....MANSONIA
   Wing scales narrow (rarely moderately broad) tip of abdomen pointed.....AEDES
10. Antennae much longer than proboscis, first flagellar segment longer than the next two combined. .....DEINOCERITES
    Antennae not longer than proboscis or only slightly so, first flagellar segment about as long as each succeeding segment..... 11
11. Fourth tarsal segment of fore tarsi very short, only about as long as wide; scutum with delicate longitudinal lines of white scales.....ORTHOPODOMYIA
    Fourth tarsal segment of fore tarsi much longer than wide; scutum without longitudinal lines of white scales..... 12
12. Wing scales very broad, brown and white mixed.....MANSONIA
    Wing scales narrow, uniformly dark.....CULEX

Larvae

1. Eighth abdominal segment without an elongate dorsal siphon.....ANOPHELES
   Eighth abdominal segment with an elongate dorsal siphon which is as long as or longer than wide. 2
2. Siphon with a pecten..... 3
   Siphon without a pecten..... 9
3. Head longer than wide; eighth abdominal segment with a prominent sclerotized plate with the comb scales on posterior margin.....URANOTAENIA
   Head at least as wide as long; eighth abdominal segment without a prominent sclerotized plate (small plate present in some species of *Psorophora*)..... 4
4. Head with a prominent triangular pouch on each side; anal segment with divided dorsal and ventral sclerotic plates.....DEINOCERITES
   Head without a prominent triangular pouch on each side; anal segment without divided dorsal and ventral sclerotic plates..... 5
5. Siphon with a pair of large basal tufts, or if tufts are small, the comb scales are arranged in a single row, and bar-like.....CULISETA
   Siphon without a pair of basal tufts or single hairs; comb scales in a patch or single row.. 6
6. Siphon with several pairs of tufts or single hairs.....CULEX
   Siphon with one pair of median or subapical tufts, (sometimes vestigial) or one pair of single hairs..... 7
7. Anal segment completely ringed by the dorsal saddle and pierced on the midventral line by tufts of the ventral brush.....PSOROPHORA
   Anal segment not completely ringed by the dorsal saddle, or if ringed, not pierced on the midventral line by tufts of the ventral brush..... 8
8. Dorsal saddle with a prominent group of long spines on posterior margin; comb scales in a single row.....HAEMAGOGUS

Dorsal saddle without a prominent group of long spines on the posterior margin, or if long spines are present on posterior margin, comb scales in a patch.....AEDES

9. Eighth abdominal segment without comb scales; mouth brushes prehensile, each composed of about ten stout rods.....TOXORHYNCHITES
Eighth abdominal segment with comb scales, either in a patch or single row; mouth brushes composed of 30 or more hairs..... 10

10. Apical half of siphon strongly tapered, with a lateral saw-toothed projection.....MANSONIA
Apical half of siphon never strongly tapered, cylindrical or spindle shaped, without a lateral saw-toothed projection..... 11

11. Anal segment with a prominent median ventral brush; comb of eighth segment with a double row of long scales.....ORTHOPODOMYIA
Anal segment without a median ventral brush, but with a pair of ventro-lateral tufts, comb scales in a single row.....WYEOMYIA

coloration of the abdominal scales and the large anterior pronotal lobes. As a group, the larvae of *Haemagogus* are inseparable from the genus *Aedes* (2). However, *H. equinus* can be separated from *Aedes* of the U. S. by the characters presented in this key. These characters are the presence or absence of long spines on the posterior margin of the dorsal saddle, and the arrangement of comb scales. The nomenclature and generic status as used by Carpenter and LaCasse (3) have been followed in part in these keys.

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RESULTS OF FIELD TRIALS WITH DDVP IN MOSQUITO CONTROL

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Late in 1951 and early in 1952, the organic phosphates, beginning with EPN, began coming into use as mosquito larvicides in California. By 1953 both parathion and malathion were being used to some extent and proved satisfactory. Their use steadily increased until by 1956 some 85,000 pounds of phosphates were used on some half-million acres annually (1).

Malathion and parathion are the two materials used, with the less hazardous malathion being preferred.

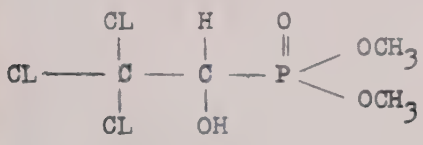
During the latter part of the 1955 and 1956 season, some areas of California's central valley noted that mosquito control with malathion was becoming more difficult. At the Twenty-Fifth Annual Conference of the California Mosquito Control Association, Inc., at San Jose, California, January 21–23, 1957, this increasing difficulty of control with malathion was the subject of considerable discussion. It was reported that in the San Joaquin Valley fourth instar larvae of *Culex tarsalis* had developed a degree of resistance to malathion of up to 33 times the normal LD 90. Adult *Culex tarsalis* in the laboratory appeared resistant to malathion up to 93 times the normal LD 50. No noticeable resistance was noticed to parathion. This may or may not be a maximum level of resistance of this species towards mal-

thion or it may be a trend toward, for all practical purposes, complete resistance. It does point up the necessity for continued research and the development of new materials or methods.

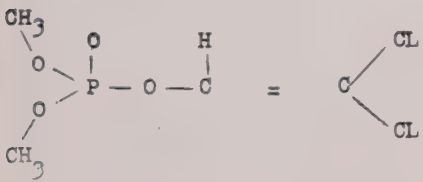
During the 1956 season, the Southeast Mosquito Abatement District, which takes in the southeasterly portion of Los Angeles County, California, had an opportunity to cooperate in work with one of the newer organic phosphates, DDVP.

This volatile, fast acting material had, in limited work, shown remarkable insecticidal powers, particularly against resistant house flies.

DDVP was discovered and its chemical structure determined by the research personnel of the Communicable Disease Center, U. S. Public Health Service (2). While conducting tests on the toxicity of vapors of various insecticidal compounds, other workers in the department had observed that one of the organic phosphate compounds under test gave unusually high fly mortality initially but that continued aeration produced no highly toxic vapors. This suggested that the initial effectiveness was due not to the compound itself but to a highly volatile impurity. The material in which the highly volatile impurity was found, Bayer L 13/59 (Dipterex) is a commercial preparation of 0,0, dimethyl, 2,2,2-tri-chloro-1-hydroxyethyl phosphonate with a structural formula:



Brilliant analytical work established that this highly volatile impurity was 0,0-dimethyl 2,2-dichlorovinyl phosphate.



The pure material is a straw-colored liquid, of about the consistency of water. Its boiling point is 84° at 1 mm.

Mammalian toxicity: Tests indicate that DDVP is about 1/10 as toxic to rats as parathion. Based on tests with rats, DDVP is not quite so toxic, relatively, as dieldrin. DDVP in common with the other organic phosphates is a cholinesterase inhibitor.

Insecticidal Properties: According to data on its insecticidal properties released by the C.D.C., U.S.P.H.S., DDVP is about 10 times as toxic as Bayer L 13/59 and equal to parathion against house flies. It has been found effective against a wide range of insects including stored products pests, cockroaches, flies, and mosquitoes.

Because of its volatility it has relatively little residual effect.

In August 1956 cooperative experimental work was initiated with Alco Chemical Company to determine the potentialities of DDVP for mosquito control. The material used in the tests was a 24.6 percent (2 lbs. DDVP per gallon) emulsifiable concentrate formulated by Alco. The site was a local cut and fill dump located in an area with a high water table. There were numerous pools of two to three foot depths available, all highly polluted with dump refuse. Three pools with a surface area of about 3,500 feet each were used for test purposes. Each of the pools had medium to heavy populations of immature forms of all stages at the time of treatment. The larval populations consisted of about 75–80 percent *Culex stigmatosoma* Dyar and 20–25 percent *Culex pipiens* Linn.

The material was applied in dilutions of 1:100, 1:200 and 1:400 or at the rates of approximately 1, 2 and 4 ounces actual DDVP per acre in 10 to 15 gallons of water. Applications were made with a 3-gallon tank type compressed air sprayer. By walking slowly around the entire periphery of the pool the coarse spray could be directed until the entire pool surface had been treated. The treatments were applied during the morning and observations made two, four and six hours later and daily thereafter. The 1:100 and 1:200

dilutions resulted in a complete kill of all stages of mosquito larvae and pupae within six hours. The 1:400 dilution killed 85–90 percent of all active stages within the six-hour period but did not give a complete kill after twenty-four hours.

Egg raft samples (50 rafts each) taken before and after treatment indicated that all dilutions were either ovicidal or killed first instar larvae on hatching as none of the post-treatment egg samples brought into the laboratory survived. The majority of the pre-treatment egg samples survived and were reared through to adults. These applications also killed most of the other insect life present in the pond, including various dipterous larvae, water beetles and back swimmers.

Two days after treatment first instar larvae began hatching in all treated pools, indicating short residual activity. It is felt that these came from egg rafts deposited some time after treatment. Population levels of all stages remained rather high in surrounding untreated water furnishing a continuing source for reinfestation of the treated pools.

This preliminary work appeared to indicate that DDVP has considerable promise in mosquito control operations.

Tests in California by other workers (3) have indicated that DDVP has given excellent results against all immature stages of mosquitoes in pastures and clear water. In contaminated waters the results were not quite so good.

DDVP at 0.1 p.p.m. has been reported (3) as highly effective against mosquito larvae and pupae and in about the same category as Thiodan, ET-14 and phosdrin.

DDVP is less toxic to warm bloods than most of the other very effective materials. It is very effective against all stages of mosquitoes at relatively high dilutions. Its short residual activity would be an advantage in many situations. In short, DDVP is a very promising new material for the control of mosquitoes.

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The above papers conclude the *Proceedings* section of Volume 17 of *Mosquito News*. There were several papers which were not submitted to *Mosquito News* either because they were not originally intended for publication or because they were to be published elsewhere. Papers which are delayed because of the necessity for revision are ordinarily published in the Articles section in a later issue.

UTAH MOSQUITO ABATEMENT ASSOCIATION

Sixty per cent of the people in the state of Utah are now living within the boundaries of organized mosquito abatement districts.

President	*Vice-President*	*Sec.-Treas.*
LEWIS T. NIELSEN University of Utah Salt Lake City, Utah	LEWIS E. FRONK Weber Co. M.A.D. Ogden, Utah	GLEN C. COLLETT Salt Lake City M.A.D. 401 City-County Bldg. Salt Lake City, Utah

Proceedings of Annual Meetings for Sale.

ARTICLES

SOME RELATIONSHIPS BETWEEN BACTERIA AND CERTAIN SEWAGE-INHABITING INSECTS[1]

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The larvae of a number of dipterous insects breed in sewage-polluted waters. There is an evident possibility that at least some of these larvae may acquire disease-producing organisms that may later be disseminated by the adult flies which often occur in enormous numbers in cities adjacent to polluted streams and lakes. In 1942 we had the opportunity to test the tenability of this hypothesis. The data obtained during this study have been briefly referred to in a previous publication (Steinhaus, 1946), but have never been presented in detail. In light of the recent report by Lysenko (1957) on this same general subject—but with different results—it would seem appropriate to present here at least a summarization of the results obtained and the conclusions reached.

The insects selected for this investigation were *Tendipes decorus* (Joh.) (=*Chironomus cayugae* Joh.) *Tendipes plumosus* var. *ferrugineovittatus* Zett., and *Psychoda* sp. The *Tendipes* species normally breed in the bottom mud of lakes and streams, and the adults are found in large numbers near water. The psychodid used in these experiments breeds in large numbers in trickling filters and the adults appear in swarms at the time of emergence. The larvae were collected in the field, placed in sewage-contaminated mud, and subsequently examined in the laboratory.

[1] This study was made in 1942 when the senior author was a member of the staff of the Rocky Mountain Laboratory (Hamilton, Montana), and the junior author was on the staff of the Stream Pollution Investigations Laboratory (Cincinnati, Ohio). Both laboratories are units of the National Institutes of Health (USPHS).

Studies on *Tendipes* spp. A total of 36 larval and 58 adult *Tendipes* were studied.

Larvae. The results of the microbiological examinations of the larvae are given in Table 1. Of 16 specimens examined, taken directly from sewage-polluted water, the body contents of 8 yielded large numbers of bacteria of which 11 strains were isolated. In order to determine whether these 11 strains were regularly and normally present in the larvae or had been ingested, a number of larvae which had been developing in sewage-contaminated mud were removed, washed several times and placed in several changes of a filter paper suspension over a period of 4 or 5 days. The body contents of 13 of 21 specimens fed on filter paper suspensions yielded 17 strains of bacteria. Nearly every one of the 13 harbored internally a gram-negative small rod which was abundant in the filter paper suspension itself. They apparently lost those bacteria that may have been originally present in their alimentary tracts. This observation indicates that the bacterial flora very probably originates in the substrate.

From these data it may be concluded that a considerable number of *Tendipes* larvae living in sewage harbor bacteria. The flora consists chiefly of gram-negative small rods (mostly coliforms, as would be expected from a sewage habitat), although gram-positive cocci and rods (including anaerobes) were likewise found. Diatoms and other algae were also present occasionally.

In a similar investigation of *Tendipes*

TABLE 1.—Bacterial flora of *Tendipes* larvae

Method of Examination	Number of Specimens Examined	Number Yielding Bacteria	Number of Bacteria Isolated	Kinds of Bacteria
Larvae from Sewage and Sewage-Contaminated Mud				
Triturated	12	7	10	8 gram-negative rods 1 gram-positive coccus 1 gram-positive anaerobe
Dissected (alimentary tract)	4	1	1	1 gram-negative rod
Totals	16	8	11	9 gram-negative rods 1 gram-positive coccus 1 gram-positive anaerobe
Larvae Fed on Filter Paper Suspension				
Triturated	17	10	14	11 gram-negative rods 1 gram-positive coccus 1 gram-positive small rod 1 gram-positive anaerobe
Dissected (alimentary tract)	4	3	3	2 gram-negative rods 1 gram-positive short rod
Totals	21	13	17	13 gram-negative rods 1 gram-positive coccus 2 gram-positive small rods 1 gram-positive anaerobe

(probably *dorsalis*) larvae, Hurley (1951) found the flora to consist of approximately 41 percent gram-negative rods, 33 percent gram-positive rods, and 25 percent gram-positive cocci. These same organisms were shown to be present in the environment of the larvae. Although we made no determinations along such lines, Bonnell and Mote (1941) state that *Tendipes* larvae may possibly use bacteria as food.

Adults. Table 2 gives the data pertaining to the emerged adults examined immediately after leaving sewage-contaminated mud and water. The procedures used excluded the possibility of secondary contamination, since aseptic techniques were employed throughout the handling and examination of the insects. Fourteen of 31 triturated specimens examined yielded abundant bacteria (22 strains); there appeared to be little difference in the bacterial flora of the males and females; about one-third of the specimens of each harbored bacteria. As in the case of the larvae, the majority of the bacteria consisted of gram-negative rods (17 out of 22 strains). Three cocci, a gram-positive small rod, and a gram-positive anaerobe were also isolated.

EXAMINATION OF INTESTINAL CONTENTS OF ADULTS. Soon after emerging, the adults frequently released small deposits of greenish intestinal fluid (meconia). For the purpose of determining if the bacteria were present in this fluid several adults were carefully and aseptically placed on solid media in petri dishes as soon as possible after emergence. After a few hours one could often find several deposits on the media. The midges were then removed and the plates incubated. The results of this experiment are given in Table 3. None of five males yielded bacteria. Four of 7 females yielded large numbers of 4 strains. These were gram-negative small rods.

TABLE 2.—Bacterial flora of adults (triturated) emerged from sewage

Sex	Number of Specimens Examined	Number Yielding Bacteria	Number of Bacteria Isolated	Kinds of Bacteria
Males	7	2	2	1 gram-negative rod 1 gram-positive small rod
Females	8	3	3	2 gram-negative rods 1 gram-positive coccus
Undetermined	16	9	17	14 gram-negative rods 2 gram-positive cocci 1 gram-positive anaerobe
Totals	31	14	22	17 gram-negative rods 3 gram-positive cocci 1 gram-positive small rod 1 gram-positive anaerobe

The following additional facts are of interest: Five of the specimens (4 males and 1 female) yielded no bacteria in their meconia, and none when triturated and cultured. One female and one male (the latter from the *Serratia marcescens* experiment which is discussed later) yielded no bacteria in their meconia but did when triturated and cultured. Another female yielded a gram-negative rod in its intestinal deposits and the same bacterium when the specimen was triturated. One male (from *S. marcescens* experiment) yielded a gram-negative rod in its intestinal deposits but none when triturated and cultured. Thus it may be seen that the intestinal contents deposited soon after emerging may or may not be sterile. Twelve of 18 that were allowed to walk on plates of solid media contaminated the plates, while 6 did not.

Of interest is the fact that Hurley (1951) has also found that the fecal material of *Tendipes* adults contains the same kinds of bacteria found in the water they inhabited during the larval stage.

EXPERIMENTS WITH *Serratia marcescens*. In an effort to trace a known organism from the sewage to the emerged adult, a 24-hour broth culture of the red-pigmented bacterium, *Serratia marcescens* Bizio, was added to the sewage in which were living the *Tendipes* larvae. When the adults emerged, they were examined for *S. marcescens* by trituration and by examination of their intestinal deposits. Only 2 of the 12 triturated adults yielded *S. marcescens* (one male and one female). Neither of these yielded *S. marcescens* when it walked over the surface of a solid medium and the bacteria were not found in the intestinal deposits. One other adult did yield *S. marcescens* when it walked over a plated medium, though when triturated this specimen was negative. No *S. marcescens* was isolated from its intestinal deposits.

KINDS OF BACTERIA ISOLATED. Since the

TABLE 3.—Bacteria in intestinal deposits of adults emerged from sewage-fed larvae

Sex	Number of of Specimens Making Deposits	Number in Which Deposits Negative	Number in Which Deposits Positive	Kinds of Bacteria
Males	5	5	0	None
Females	7	3	4	4 gram-negative rods
Totals	12	8	4	4 gram-negative rods

insects studied in this investigation did not appear to possess a characteristic bacterial flora of their own, detailed identifications of the various strains isolated were not carried out in all cases. As was to be expected, most of them were coliforms. The 71 strains isolated consisted of the following morphological types:

56 gram-negative small rods
3 gram-positive small rods
7 gram-positive cocci
2 gram-positive spore-forming aerobes
3 gram-positive spore-forming anaerobes

STUDIES ON *Psychoda* sp. Nineteen strains of bacteria and 1 fungus were isolated from the body contents of 18 specimens (8 adults and 10 larvae) of *Psychoda* sp. From the 4 adults, 6 strains of bacteria (2 gram-positive cocci, 3 gram-negative rods, and 1 gram-positive small rod) were isolated. The other 4 specimens were sterile. From the 10 larvae, 13 strains of bacteria (all gram-negative small rods) and 1 fungus were isolated. None of the larvae was sterile.

DISCUSSION AND SUMMARY. Fifty to one hundred percent of the individual specimens of several lots of the larvae of the *Tendipes* and *Psychoda* studied were found to contain bacteria. Forty-five to fifty percent of the adults were shown to harbor the same types of bacteria as found in the larvae. Most of the bacteria isolated from both the adults and the larvae were coliforms (79 percent). The larvae fed on filter paper suspensions were found to contain the same types of bacteria as found in the suspensions themselves, and they harbored as many bacteria as the larvae feeding on sewage.

Approximately 33 percent of the adults releasing the initial intestinal fluid ordinarily exuded after emergence, deposited bacteria, nearly all of which were coliforms.

One may assume, therefore, that the adults' emergence from sewage can spread sewage bacteria by their intestinal deposits. They might also spread bacteria by contact since 66 percent of the adults that walked over the plates yielded bacteria. Where these midges occur in enormous numbers they cause considerable loss and annoyance by getting into food and other materials used by people.

The results obtained in the experiments recorded here indicate that insects, such as species of *Tendipes* and *Psychoda* that may live as larvae in sewage, are capable of acquiring microorganisms during the larval stage and later of disseminating them during the adult stage. This conclusion is confirmed by data obtained in a subsequent but similar study by Hurley (1951). The fact that Lysenko (1957) found that certain test bacteria did not accompany *Tendipes plumosus* throughout its metamorphosis may possibly be explained on differences in the microorganisms and testing procedures used.

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Be sure to plan ahead for the AMCA meetings and make your hotel and travel reservations in plenty of time. Remember, February 22 is a holiday and it may be difficult to arrange for travel the last minute.

THE CASE OF THE VANISHING BRICK DUST [1]

Contribution to Knowledge of Marsh Development

L. A. STEARNS and DONALD MacCREARY
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Since 1932, the Department of Entomology of the Agricultural Experiment Station of the University of Delaware has been engaged in an investigation of mosquitoes. The cost of this research program from 1932–33 to 1956–57, inclusive, approximates $226,000.00. Results, during this 25-year period, have been summarized in 52 publications authored by 23 individuals. Their combined contributions amount to a 616-page volume embracing all of the important aspects of local biology and control.

One of these publications (Stearns, MacCreary and Daigh, 1940), reports upon work to determine the effect of ditching for mosquito control on the muskrat population of a Delaware tidewater marsh. While this study was in progress (1936–39), the experimental site was visited by many interested specialists in this general field. Such a group, accompanied by the writers, inspected the area on May 5, 1937. Included were: G. H. Bradley, F. C. Bishopp and J. A. Rowe (then with the USDA, Bureau of Entomology and Plant Quarantine); W. S. Bourn (then with the USDA, Bureau of Biological Survey); and A. P. Dachnowski-Stokes (then with the USDA, Soil Survey Division, Bureau of Chemistry and Soils).

For the purpose of frequent and accurate evaluation of the effect of ditching in its many ramifications, the entire acreage (both ditched and unditched sections) had been subdivided into 100-foot-square (or sometimes even smaller) units, and the vegetative cover had been mapped on the scale of one-sixteenth of an inch to a foot (see Fig. 12, p. 24, Stearns *et al.*, loc. cit.).

Most of the ecologically significant plants common to Delaware's lowlands occurred here. Those of economic value appeared in practically pure stands of varying size; for example, big cordgrass (*Spartina cynosuroides*), saltmarsh cordgrass (*S. alterniflora*), saltmeadow cordgrass (*S. patens*), saltgrass (*Distichlis spicata*), Olney's three-square (*Scripus olneyi*) and several others.

Obviously, information concerning the plants that had been involved in the gradual formation of this marsh over the years would be of considerable value in providing a phyto-historical background for the present. Units 19, 20, 28, 29, 39 and 40 composed a rectangular (200′ x 274′) relatively homogeneous area, with Olney's three-square, saltmeadow cordgrass and saltgrass dominant and spikerush (*Eleocharis rostellata*) secondary constituents, respectively, in the plant association at that point. Arbitrarily selecting unit 40 and by means of a peat-sampling device, Dr. Dachnowski-Stokes removed a series of soil samples, to a depth of 15 feet (for his dictated descriptions of the same, refer to footnote, p. 19, Stearns *et al.*, loc. cit.). Well-preserved remnants of *S. olneyi* at the 15-foot level indicated (in his opinion) that the species existent ages ago were, in all probability, identical with those of today.

It is a well-known fact that a marsh of this kind develops by accretion; that is, by continued and appreciable accumulations of vegetative-cover debris eventually fixed in place by the mud from tidal waters. At the suggestion of Dr. Dachnowski-Stokes, four bushels of brick dust were spread evenly (as a one-inch layer) over 25 square feet in the center of unit 19 on May 17, 1937; there to remain for 20 years, at

[1] Published as Miscellaneous Paper No. 288 with the approval of the Director of the Delaware Agricultural Experiment Station. Publication 290 and Scientific Article 206 of the Department of Entomology, September 6, 1957.

FIG. 1.—Layer of brick dust, four to five inches below marsh surface, July 15, 1957.

which time the position of this distinctive marker in the soil was to be determined as indicative of the rate of marsh build-up.

On July 15, 1957, the situation in unit 19 was viewed again. There had been no discernible change in plant types since 1937. The layer of brick dust was now situated from four to five inches below the marsh surface (Fig. 1), or an increase by external addition in terms of about one inch in every four years.

Apparently, however, the complicated chemical and physical processes responsible for decomposition and stratification (as observed and recorded on May 5, 1937) are sufficiently effective to compensate fully for annual increments of dead growth at the top level. In other words, the ground elevation in unit 19 is now, for all practical purposes, the same as determined 20 years ago.

The present elevation is 5.625 feet above local mean low water (average of 50 readings on August 30, 1957) compared with an average of 5.686 feet for the four years, 1936–39. The difference (0.061 foot or less than ¾ of an inch) is well within the range of instrumental accuracy, when operating on a spongy marsh soil with a very high water table (only 3.52 inches below ground surface; reference: Tables 3 and 4, pp. 30–31, Stearns *et al.*, loc. cit.). The weight of the rodman alone on the highly-saturated unstable substratum at the many elevation points will account for all of the small variations from the average registered in this recent survey.

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SOME TECHNIQUES FOR COLLECTING TREE HOLE BREEDING MOSQUITOES [1]

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The University of Texas

In many parts of the world including the United States, there are species of mosquitoes that breed routinely in tree holes that contain water. Many of these mosquitoes apparently prefer this type of breeding environment, and certain species are of considerable medical importance.

The possible significance of mosquitoes of this type has been recognized for many years, and recently several papers have re-emphasized their potential importance (i.e. Breland, 1957; Bonnet and Chapman, 1956; Trapido and Galindo, 1956).

The writer and his associates have been collecting tree hole breeding mosquitoes intermittently for many years, and for the past year or so have concentrated upon these species. The reason for this recent concentration was the recovery in 1955 of *Haemagogus equinus* Theobald near Brownsville, Texas (Trapido and Galindo, 1956). This species, one of the so-called jungle mosquitoes, could be of considerable importance in the epidemiology of yellow fever.

In Texas, where most of our collecting has been done, seven species of mosquitoes in addition to *Haemagogus equinus,* routinely breed in tree holes. These include *Aedes thibaulti* D. and K., *A. triseriatus* Say, *A. zoosophus* D. and K., *Orthopodomyia alba* Baker, *O. signifera* (Coq.), *Toxorhynchites rutilus septentrionalis* (D. and K.), and *Anopheles barberi* Coq.

As might be expected, the species of trees with suitable cavities for mosquito breeding varies in different areas. Trees from which good collections have been recovered include live oak (*Quercus virgina*), elm (*Ulmus crassifolia*), hackberry (*Celtis* sp.), willow (*Salix* sp.), Texas ebony (*Pithecolobium flexicaule*) and a type of mimosa (*Leucaena pulverulenta*).

So far we have not discovered any of the species of mosquitoes showing selectivity in the species of tree used for breeding. *Aedes thibaulti* is reported to be more or less limited to sweet-gum and tupelo-gum trees (Carpenter and La Casse, 1955) but we have not collected a sufficient number of this species to form an opinion of its habits in this area. *Haemagogus equinus* has been collected on several occasions from Texas ebony, and there was for a time some indication that this species might prefer small cavities in this species of tree in this area. However, we recently collected this mosquito from a large cavity approximately 6 inches in diameter and 12 inches deep in a hackberry. This tree was in a region of thick vegetation which limited the amount of light which reached the cavity. At present we feel that environmental factors, such as light, are perhaps more important than the species of tree in determining the breeding habitat of this species.

The writer does not claim that the techniques to be outlined are completely original. Some of these have been mentioned in previous publications (e.g. Jenkins and Carpenter, 1946) and are considered to be standard methods of collecting tree hole mosquitoes; the new or modified procedures are a result of the experiences of many individuals. In view of the impor-

[1] Supported by a grant, Contract No. DA-49-007-MD-744, Research and Development Division, Office of the Surgeon General, Department of the Army.

[2] Individuals who have helped in the development of the techniques herein outlined include Dr. James D. Long, Dr. Orin P. Wilkins, John G. Riemann and Fred Klaus.

tance of this ecological group of mosquitoes, however, it is believed that some of the techniques used successfully by us may have a certain value to other workers.

COLLECTING EQUIPMENT. Much of the equipment and the procedure used in transporting living specimens is the same as that outlined in a former paper (Breland, 1954) for general collecting. The collecting of immature stages rather than adults is emphasized. Living larvae are transported to the laboratory in large mouth pint, quart and half gallon fruit jars with fine mesh wire lids; the containers are partitioned boxes lined with cork.

Equipment used primarily for tree hole collecting includes an assortment of large pipettes with bulb capacities of from 25 c.c. to 8 ounces (approximately 240 c.c.); eight-ounce capacity bulbs to which rubber or plastic tubing of varying lengths is attached; small cloth bags approximately 4½ x 6½ inches with draw strings; flashlights, scout axes, and an aluminum step ladder four feet in height. Several of the half-gallon jars are filled with strained pond water at the beginning of each collecting trip, and as it is used, it is replaced from roadside ponds and streams. The uses of the equipment and water will be noted shortly.

GENERAL COLLECTING TECHNIQUES. Problems involved in collecting immature stages of tree hole breeding mosquitoes include the dark color of most tree hole water, the relatively small amount of water involved, and the fact that most tree holes are less accessible than the breeding habitats of most other species. Many tree holes occur six to ten feet above the ground, and the step ladder allows holes at this height to be more readily accessible. Tree hole water is sometimes so dark that it is difficult or impossible to determine under field conditions whether or not specimens are present in a given collection. Sometimes larvae can be seen by pouring small amounts of water into a white enamel dipper, but young instars or eggs might be present and not discovered. All water in a tree hole is routinely taken and the hole flushed with pond water previously mentioned. This water may be added to the original water, or in some cases, a separate jar is used for the flush water.

At the end of the day's collecting, each collection is examined by pouring small amounts of the water into a large white enamel pan. If larvae are present, some are preserved, using 95 percent alcohol. The larvae are first rinsed in clear water, then placed in small screw top vials. The alcohol is added to the vial with the larvae. The small amount of water that is present dilutes the preservative somewhat. A data label is placed inside the vial and a plug of absorbent cotton inserted to hold the specimens in place. The remainder of the larvae in each collection are returned to the collecting jars for transportation to the laboratory.

The methods used for removing water from tree holes vary with the situation. Sometimes openings are so small that they must be enlarged with a hand ax. If possible, pipettes are used to remove the water, but the bulb-tube combinations are employed for holes not accessible to the pipettes. After each collection, all collecting equipment is thoroughly rinsed in pond water to avoid contaminating the next collection.

It has been noted previously (Breland, 1954) that larvae and other immature stages have been transported successfully for several hundred miles in the wide mouth fruit jars with wire tops used for this purpose. When collecting with specimens in the car, care is taken to have good ventilation, and if possible to park in the shade to keep the specimens cool. When feasible, collecting jars with specimens are left at the sleeping quarters during the day while collecting.

The discussion so far applies primarily to routine collecting when rainfall has been sufficient to deposit water in many tree holes. Other methods, as noted below, have been used with some success when a high percentage of collecting sites

have insufficient water. As will be mentioned, the percentage of successful collections using these methods varies with environmental conditions and with the various species of mosquitoes.

Collecting Dry Material. In the absence of free water, dry or moist material from tree holes is collected, put in small cloth bags and flooded later in the laboratory. In obtaining this debris, care is taken to scrape the sides of the cavity thoroughly to recover any eggs that might occur here. The percentage of recoveries using this method is apparently dependent upon climatic conditions. For example, during periods of intermittent rainfall, our recoveries have been from approximately 35 percent to more than 50 percent. In years of drought, such as occurred in Texas in 1956, successful collections have been less than 4 percent. This latter figure is based upon more than 90 collections of moist and dry material along the Texas-Mexico border with the most widely separated localities more than 500 miles apart. The absence of free water in tree holes for long periods during drought may account for this very small percentage of recovery. Several species are reported to deposit their eggs just above the water line and it may be that eggs are laid only when some water is present.

To date, the only species collected by us in this way have been *Aedes triseriatus* and *A. zoosophus*. Dunn (1926), however, reports the collecting of eight species of *Aedes* including *A. aegypti* L., from west Africa, and it seems probable that most tree hole breeding *Aedes* and other species with similar egg laying habits could be recovered by this method.

Addition of Water. Not infrequently, tree holes are moist but either have no free water or an insufficient amount for a collection. Under these circumstances, the hole is filled with water, the water removed and the hole flushed several times. Larvae of *Orthopodomyia alba* Baker were first collected in Texas by using this method (Breland, 1947) and since that time other species have been recovered.

The addition of water to moist or dry holes and leaving it for 24 to 48 hours before collecting has proven successful on several occasions. This method has been more successful within a few days after a rain rather than during periods of drought. Species that have been recovered by this method include young instars of *Haemagogus equinus, Aedes zoosophus* and *A. triseriatus*.

Laboratory Procedure. In the laboratory, large collections of larvae are placed in white enamel pans approximately 14 x 8½ x 2½ inches for rearing. Smaller pans and finger bowls are used for small collections. If the tree hole water is too dark for easy observation, it is often diluted with pond water. As a rule, compressed air is bubbled through an air stone placed in one end of each rearing pan. This air helps to prevent the formation of scum, and apparently contributes to a higher survival rate. As pupae are formed in the pans, they are transferred to small staining dishes and placed under bell jars or into cages for emergence.

Dry and moist material is flooded as rapidly as facilities permit, but until this time, it is kept in a box to prevent it from becoming too dry. As a rule, material that yields larvae will do so at the first flooding, but there are exceptions. For example, no larvae appeared in one sample until it had been dried and flooded three times. Five larvae of *A. zoosophus* appeared at the third addition of water.

The number of specimens recovered can often be materially increased by drying and flooding several times. Dr. Orin P. Wilkins, former student of the writer's, once obtained more than 800 larvae of *A. zoosophus* from a sample that was dried and flooded twelve times over a period of a year. Only about 300 larvae appeared at the first addition of water.

Collections of water or of dry or moist material that do not yield any larvae within 72 hours are assumed not to contain any eggs, and these are discarded if the rearing pans are needed for other work. We have on numerous occasions

kept such samples for more than a week, and have never yet had larvae appear for the first time after 72 hours of exposure to water. Sometimes additional specimens apparently hatch after this time, but in all such instances, some larvae have appeared earlier. It is recognized that an occasional collection of water might contain freshly deposited eggs that would not hatch within 72 hours, and for this reason, collections are kept for a longer period whenever possible.

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OBSERVATIONS OF A LABORATORY COLONY OF THE MOSQUITO *CULEX TRITAENIORHYNCHUS* GILES [1]

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INTRODUCTION. Since the publication of the preliminary report on the laboratory colonization of *Culex tritaeniorhynchus* (Newson, Blakeslee, *et al.* 1956) more detailed observations have been made on the bionomics of the colony and a more complete evaluation has been made of some of the changes noted in the behavior of this species during its adaptation to the laboratory environment. The following account includes information collected subsequent to the preparation of the preliminary report, a description of some of the adaptive changes observed in the early generations of the colony and the procedures followed in establishing a subcolony in a small cage in this laboratory.

COLONY BIONOMICS. The stock colony is now in the estimated twelfth generation and still is maintained in the large room-sized cage under the conditions described in the preliminary report. Egg raft viability has increased slightly above that reported for the sixth generation and approximately 97 percent of the egg rafts currently produced contain viable eggs. The size of the egg rafts may vary considerably. A group of over 200 egg rafts selected at random from those produced over a period of three weeks contained from 97 to 427 eggs each with an average of 214 eggs per raft. An average of 90 percent of the eggs in each of these 200 rafts was viable.

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The average duration of the larval and pupal stages has not changed. Development may be retarded several days by lowering the temperature, but a critical study has not been made of the effect of temperature fluctuations on the time required for larval and pupal development.

Under the conditions maintained in the laboratory colony, males have not been observed to live more than 29 days while the maximum female longevity observed thus far was 107 days. One female produced a normally formed, viable egg raft when 102 days old and took a full blood meal from a rabbit the following night. This female had been isolated from males for 78 days prior to the date the egg raft was produced. The stage in which this species naturally overwinters in Japan is not known. On the basis of this laboratory evidence, it seems quite likely that, from the viewpoint of longevity, some adult female *Culex tritaeniorhynchus* should be able to overwinter successfully and be capable of taking blood meals and producing viable egg rafts in the spring when they again become active.

Some females in the laboratory have become inseminated and have taken their first blood meal as early as 56 hours following emergence. They have produced viable egg rafts 4 days after the blood meal. The majority, however, do not mate or take their first blood meal until 7 to 8 days after they emerge. Some females have been observed to mate repeatedly while there are some which apparently do not become inseminated or take a blood meal during their entire lifetime. Some are known to mate prior to taking a blood meal and others mate afterwards but detailed studies have not yet been made to determine what correlation, if any, exists between these two activities.

A limited study completed by the Virus Department of this laboratory indicated that the mosquitoes in this laboratory colony have retained, to date, their ability to transmit the virus of Japanese B encephalitis in laboratory animals (Gresser, *et al.*).

Growths of protozoa, *Vorticella* sp., occasionally have been observed on pupae and fourth instar larvae in the rearing containers. The infested individuals are sluggish and move slowly when disturbed. While mortality is high in these larvae and pupae, apparently normal adults have developed from individuals which supported very heavy growths of protozoa during their immature stages. The nature and extent of the injury caused by these protozoa has not yet been determined.

Behavior Changes. Green filamentous algae, mainly *Spirogyra* sp., were added to the larval rearing media during the first three generations of the colony, since *C. tritaeniorhynchus* larvae frequently had been observed grazing on algae of this type in natural breeding sites. After the second generation the larvae in the colony no longer ate the algae so its use was discontinued.

Several changes have been noted in adult behavior during the adaptation of the colony to laboratory conditions. The females originally were quite reluctant to feed on humans but now do so readily. Although swarming still occurs both mornings and evenings, the swarming activity has been modified somewhat. In the early generations of the colony, swarming activity in the evening began when a small number of males would begin to swarm near the floor in the dark corners of the cage. Additional males joined and these small swarms slowly increased in size, moved towards the center of the cage and merged into one large swarm as the cage became darker. Copulation occurred as females flew into the swarm. The females apparently were attracted to the swarm by the sound produced by flying males for, when the air conditioning system and aquarium aerators were turned off during the swarming period, females flew from all parts of the cage directly to the swarming males. When this equipment was kept in operation, however, the only females that entered the swarm were those which apparently encountered it during random flight around the cage. The aerators, therefore, are routinely turned off during swarming. At the present

time males no longer form small swarms as a prelude to general swarming activity. Swarming occurs throughout the entire cage in the mornings and evenings when light intensity is approximately one foot candle or less and both males and females actively participate in the swarming flights. The flight of both males and females during the morning and evening swarming is much more rapid and erratic than observed during the early stages of colony development and the spatial requirement for the swarming flight is much less.

From May, when the colony was started, until September natural daylight entering the cage through windows provided the only illumination except for the overhead fluorescent lights which were used on cloudy days. Several series of light intensity readings were made in the cage during the dawn, mid-day and dusk periods in June, July and August and detailed notes were made on the behavior of the adults at the various light intensities. The lower light intensities were measured with a Model 200-M Photovolt Exposure Meter and the higher ones with a Model 8DW58Y4 General Electric Exposure Meter. During the last two weeks of September the flying, feeding and mating activity and egg production of the colony were observed to be steadily decreasing. Several females taken from the cage during a routine examination on September 26 were found to have well developed fat bodies. No extensive fat body development had been found in any of the colony females prior to this time. The only conditions changed in the cage between summer, when the adult activity was high, and September, when the described trend towards hibernation was observed, was a decrease of approximately two hours in the time the cage was exposed to light each day. On September 29 the light schedule described in the original report was started. This approximated, both in the intensity and duration, the light conditions recorded in the cage in mid-summer. Within two weeks after the artificial lighting schedule was started, the feeding, flying and mating activities had risen to their former levels. Egg raft production rose sharply and from 94 to 98 percent of all egg rafts produced contained viable eggs. The same light schedule is still being used and the level of activity in the colony remains essentially unchanged.

Major Herbert Barnett, in personal correspondence, stated that in attempts to establish a subcolony of *C. tritaeniorhynchus* at the Walter Reed Army Institute of Research from material shipped to him from this laboratory, it was necessary to maintain a daily photoperiod of 15 hours in order to maintain a satisfactory level of adult activity. It thus appears that one of the critical factors in maintaining adult activity in a laboratory colony of this species is the daily period to which it is exposed to light. A daily exposure period of 15 hours is adequate to maintain adult activity in the colony while a reduction of two hours in the light period may cause a sharp decrease in feeding and mating activity and result in gonotrophic dissociation in the females.

SUBCOLONIZATION IN A SMALL CAGE. A self-sustaining subcolony is now established in this laboratory in a 3 x 3 x 3 feet screened cage. Several groups of pupae were taken from the main colony in October, when it was in the estimated fifth and sixth generation, and placed in the small cage. Adults emerging into the cage were given fresh apple slices, cotton, wads soaked in 2 percent sugar solution and a rabbit as food sources. This small cage was kept at the same temperature and relative humidity and exposed to essentially the same artificial light schedule as the main colony. Larvae were reared outside the cage using the same technique as for the main colony and the pupae were removed from the rearing containers and placed back into the cage where the adults emerged. Seventy-one percent of the egg rafts produced by the first generation and 94 percent of those produced by the second generation contained viable eggs. The subcolony is now in the estimated seventh generation and produces an average of 10 egg rafts per day. Approximately 97 per-

cent of the rafts currently produced contain viable eggs. The rafts compare favorably in size with those produced in the main colony. The adults are large and vigorous and mating and feeding activity remains at a high level.

Summary. Ninety-seven percent of the egg rafts now produced by the stock colony of *Culex tritaeniorhynchus* at the 406th Medical General Laboratory contain viable eggs. The rafts containing viable eggs have an average of 214 eggs per raft of which an average of approximately 90 percent hatch. When maintained at 75° F. and a relative humidity of 80–95 percent no males have been observed to live more than 29 days while females have produced viable eggs at 102 days, taken a blood meal at 103 days and remained alive and active up to 107 days after emergence. Females may take blood meals and mate as early as 56 hours after emergence and can produce viable eggs four days after a blood meal. During adaptation to laboratory conditions changes were noted in the feeding behavior of both larvae and adults and the swarming behavior of adult males and females was modified. Females in the colony have retained, to date, the ability to transmit the virus of Japanese B encephalitis in laboratory animals. It appears that a daily light exposure period of approximately 15 hours is necessary to keep adult feeding and mating activity at a level high enough to establish and maintain a colony of this species in the laboratory. A self-sustaining subcolony has been established in a 3 x 3 x 3 feet cage by using essentially the same rearing technique and lighting schedule as is employed in the stock colony.

Acknowledgment. The authors wish to express their appreciation to S. Toshioka, M. Sakai, T. Shimada, J. Akiyama, Sp/3 R. G. Laraway and Pfc. C. R. Pearce for their assistance.

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A BRIEF NOTE ON BREEDING PLACES OF *CULICOIDES* IN SÃO VICENTE, BRAZIL

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There has been little research on breeding places of *Culicoides* in the neotropical region. We know only the work of Lutz (1912) in Brazil, and that of Carpenter (1951) and Woke (1954) in Central America. No other extensive investigation was made. Therefore, our observations on the subject may be of interest.

We have been studying the biology of these Diptera since August 1955, in the vicinity of São Vicente on the south coast of Brazil. Special attention was given to the search for breeding places. That city, which is adjacent to Santos, is surrounded by tidal marshes, with a few elevated areas containing low vegetation. Several channels cross these marshes and communicate directly with the ocean.

The sampling method we used was essentially the same as that used by Carpenter (1951). Mud samples of about 500 c.c. volume were collected in the edges as well as in the shallow bottom of several water accumulations. They were put in enameled vessels in the laboratory, flooded with tap water and allowed to stand overnight. The next day they were examined for larvae and pupae. Immature stages were collected at the edges of the vessels where the larvae, swimming with serpentine movements, could be seen easily. In this way we collected and examined 189 samples, of which 56 had immature forms of *Culicoides*.

We have found *Culicoides maruim, C. insignis, C. guyanensis* and *C. reticulatus*. The collections were made in several locations and the results may give some knowledge about the preferred larval habitat. *C. maruim* was found in mud of tidal marsh and edges of channels (Figs. 1 and 2), containing decomposed organic matter. It was very difficult to detect, and not many were found. *C. insignis* was taken from ditches whether or not they were flooded by salt water at high tide (Figs. 3 and 4), but it was seldom collected in the mud around mangrove roots (*Rhizophora*). This species was taken also from crab holes of *Oedipleura*.

C. guyanensis was recovered from several ditches (Fig. 5) with poor vegetation and in places fully exposed to the sun throughout the day. Some of these ditches were in contact with salt-water. *C. reticulatus* was found only in the mud collected at bottom of crab holes of *Cardisoma guanhumi* (Fig. 6), as was already described by Lutz (1912).

Such findings suggest that *C. maruim* and *C. reticulatus* have more or less well defined breeding places: the first in the tidal marshes and the second in crab holes of *Cardisoma*. On the other hand, these observations lead us to suppose that *C. insignis* and *C. guyanensis* endure great variations in the composition of water and mud of their breeding places.

SUMMARY. We have presented a brief note on breeding places of *Culicoides* at São Vicente, Brazil. There are few data on this subject in the neotropical region. Immature forms of *C. maruim, C. insignis, C. guyanensis* and *C. reticulatus* were found. The former and the latter seem to have the more restricted habitat.

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Fig. 1. Tidal marsh where immature *Culicoides maruim* were recovered.
Fig. 2. Channel in the edges of which pupae of *Culicoides maruim* were taken.
Figs. 3 and 4. Ditches where larvae and pupae of *Culicoides insignis* were found.
Fig. 5. Drainage ditch, habitat of immature *Culicoides guyanensis*.
Fig. 6. Crab hole of *Cardisoma guanhumi* at bottom of which immature stages of *Culicoides reticulatus* were collected.

A NEW ARTIFICIAL BREEDING PLACE FOR MOSQUITOES IN NEW MEXICO[1]

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Within the past decade, game watering devices, called gallinaceous guzzlers, have come into general use in water-deficient areas of the Southwest and, at least in New Mexico, have become the breeding place of mosquitoes. Since 1950, the New Mexico Department of Game and Fish has placed in operation 181 of these watering units designed exclusively to furnish water to quail and other upland birds in the arid and semiarid areas of less than 6,500 feet elevation in the southern three-fourths of the state. Each guzzler is essentially an underground cistern constructed of concrete or fiber glass, measuring about five feet wide, 10 to 12 feet long, and about 2½ feet deep, and with a maximum storage capacity of between 650 and 700 gallons. Several inches of earth piled on the arched concrete or fiber-glass roof helps stabilize water temperatures and reduce evaporation. Water from natural precipitation is directed into the cistern from an adjacent collecting apron paved with concrete or asphalt. Birds gain access to the water by walking through a slit-shaped opening, about five feet long and six inches high, and down a ramp sloping inward from ground level to the bottom of the tank near the center. The guzzlers have proved effective in providing water throughout the year and almost invariably retain water even during periods of several consecutive years of drought. It is evident that the guzzlers are successful as permanent water holes for game birds.

[1] This work was done in part under Pittman-Robertson Project W-70-R.

Soon after the first New Mexico guzzlers were placed in operation, numerous organisms, including mosquito larvae, were found developing in some of the completed tanks. Records made during the past few years indicate that, for 129 guzzlers checked more or less regularly, 54 or 41.9 percent harbored mosquito larvae, or pupae, or both on one or more occasions. There is every reason to expect all the guzzlers to be capable of serving as a suitable habitat for larval mosquitoes. Field observations indicate that there is considerable variation in the extent to which a particular guzzler may support a mosquito population. In some guzzlers, mosquito larvae are found on virtually every examination, while occurrence is sporadic in other guzzlers. Most mosquito larvae were observed to be concentrated in the less strongly shaded shallow water adjacent to the ramp, but on looking through the usually covered manhole, some larvae have been observed in the deeper and more strongly shaded water far from the opening to the ramp. Whether the cistern is of concrete or fiber glass appears to have no relationship to the numbers of mosquito larvae present and there appears to be no particular correlation between the presence of larvae in general and the season of the year or the location of the guzzler. At least some guzzlers in every area of the state have been found to harbor mosquito larvae.

Adult mosquitoes are frequently numerous in the vicinity of guzzlers and in some cases it is almost unbearable to remain motionless near a guzzler. On removing the manhole cover, adult mos-

quitoes are often observed hovering over the water without being concentrated in any particular part of the guzzler.

Between 1951 and 1956, inclusive, 32 representative collections of mosquito larvae were made from 30 different guzzlers in 10 different counties of the central and southern parts of New Mexico. The four species identified in these collections have previously been recorded from New Mexico (Ferguson and McNeel, 1954). All four are known to bite humans and two of the four have been shown capable of transmitting encephalitis virus (Carpenter and LaCasse, 1955). The most commonly found mosquito species is *Aedes atropalpus,* which was taken in 23 collections from guzzlers in nine different counties between June 1 and November 1. Seven collections of *Culiseta inornata* were taken from guzzlers in four counties during the months of September to January, while *C. incidens* was found in four guzzlers from four different counties, with collections confined to the months of October, December, and January. The least common species is *Culex salinarius,* which occurred in two collections, both taken during September, one from a guzzler in Santa Fe County and the other from a guzzler in Doña Ana County. Additional collecting may well show the presence of other species, although restrictions imposed by microenvironmental conditions within the guzzler may preclude utilization by a wide variety of species.

The authors do not wish to imply a probable public health importance in the local increase of native mosquitoes resulting from the installation of guzzlers in remote semiarid and arid range lands that otherwise are inhospitable to mosquitoes. It seems appropriate, however, to call attention to the guzzler as an artificial habitat that allows the occasional development of a dense population of pestiferous mosquitoes. The advisability of and need for control are beyond the scope of this paper.

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OBSERVATIONS ON MOSQUITO SPECIES IN NASSAU COUNTY, LONG ISLAND, N. Y., BASED ON LARVAL AND ADULT COLLECTIONS DURING THE TEN-YEAR PERIOD 1947–1956

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The collection and identification of mosquitoes are routine activities in the mosquito control program conducted by the Nassau County Department of Public Works. Daily collections are made from eleven standard New Jersey type mosquito light traps operated in locations on the south shore of the county, from May to September. Larval samples are taken also from breeding sources discovered by field inspection crews. Species determinations are made in the laboratory, and findings are recorded.

The information for this paper has been

obtained from larval and adult collection records covering the ten-year period 1947–1956. Eighteen species were recorded during this period. The notes presented below for each species give the types of breeding sources, larval association and seasonal occurrence in larval and adult stages. When observations on biting habits were made they are also given.

Anopheles crucians Wiedemann. Few larvae were collected from August to September in fresh-water ponds; larval association with *An. punctipennis*. Small number of adults taken in light traps from August to September.

Anopheles punctipennis (Say). Larvae were collected from July to September in streams, pools and ponds; maximum collections taken in August; larval association with *Culex pipiens* in fresh-water streams, with *An. quadrimaculatus* and *An. crucians* in f.w. ponds and with *Aedes canadensis* in woodland pools. A few adults were taken in light traps from July to September.

Anopheles quadrimaculatus Say. Larvae were collected from July to September in fresh-water ponds; maximum collections taken during August and early September; larval association with *An. punctipennis, Culex territans* and *Uranotaenia sapphirina*. A small number of adults were taken in light traps during August and female specimens have been taken in shelters from September to March.

Aedes canadensis (Theobald). Larvae were collected from March to August in fresh-water woodland pools and swamps; maximum collections taken in April and May, the number of collections dropping sharply after May. Larval association with *A. cantator* in pools adjacent to salt marsh, with *An. punctipennis, Culex territans* and *Aedes vexans* in woodland pools, with *Culex restuans* in f.w. swamps and pools, and with *C. pipiens* in f.w. swamps. Very few adults taken in light traps. Observed in woodland during daytime with few biting.

Aedes cantator (Coquillett). Larvae collected from April to September in ditches, wet areas, holes and pools on or adjacent to salt marshes; maximum collections taken from May to July. Larval association with *A. sollicitans* and *Culex salinarius* on salt marshes and with the following species in fresh-water pools on or adjacent to the salt marsh: *A. canadensis, A. vexans, C. pipiens* and *C. restuans*. Adults were taken in all light traps from May to September, maximum catches occurring during August. Observed biting outdoors in salt marsh areas and upland areas day and night.

Aedes sollicitans (Walker). Larvae collected from May to October in the following types of breeding places on salt marshes: ditches, flooded areas, pools, holes and bogs; maximum collections taken in June, August and September. Larval association with *A. cantator, A. vexans, Culex pipiens* and *C. salinarius* in pools and ditches on the upper salt marshes. Adults were taken in all light traps from May to September, the maximum catch occurring during August. Observed biting outdoors in salt marsh and upland areas day and night, and at times in screened porches.

Aedes triseriatus (Say). Larvae were collected from April to July in rot cavities of trees. No larval association with the exception of one instance in which larvae were found in a wooden barrel in association with *Culex restuans*. Adults taken in light traps during July. Observed biting outdoors at dusk.

Aedes taeniorhynchus (Wiedemann). No larvae collected. A very few adults taken one year in one trap location during August.

Aedes vexans (Meigen). Larvae collected from April to September in fresh-water swamps, ditches, pools and flooded areas (rain-water); maximum larval collections taken during April and May. Larval association with *A. cantator, A. sollicitans* and *Culex salinarius* in wet areas on upper salt marshes, with *C. pipiens* and *C. restuans* in f.w. swamps and wet areas, with *A. canadensis* in woodland pools, and with *C. territans* in f.w.

ditches. Adults taken in all light traps from May to September, maximum catches occurring during June. Observed biting outdoors day and night.

Culex pipiens Linnaeus. Larvae collected from May to October in the following types of fresh-water breeding places: pools, swamps, ponds, streams, ditches, dumps, excavations, cellars, sewage disposal beds, cesspools, manure piles, street catch-basins, street gutters, roof gutters and artificial containers of every description. All breeding places were in the proximity of homes and contained rainwater or ground water not affected by daily tides. Maximum collections were taken from July to September. Larval association occurred with *C. restuans* in catch-basins, swamps, pools, ponds, streams and manure piles, with *C. salinarius* in pools on upper salt marshes and adjacent upland, with *Aedes cantator* and *A. sollicitans* in ditches on upper salt marshes, with *A. vexans* in upland swamps and wet areas, with *C. territans* in f.w. streams and swamps, with *A. canadensis* in woodland pools, and with *An. punctipennis* in f.w. streams. Adults were taken in all light traps from May to September, the maximum catch occurring during August. Observed biting outdoors and indoors during day and night. Females found indoors throughout winter and early spring.

Culex restuans Theobald. Larvae collected from May to September in fresh-water swamps, streams, pools, ponds, artificial wooden containers, catch-basins and manure piles; maximum collections taken from June to August. Larval association with *C. pipiens* in swamps, pools, ponds, streams, catch-basins and manure piles, with *Aedes vexans* in swamps, with *A. cantator* and *C. salinarius* in f.w. pools on or adjacent to salt marshes, with *C. territans* in f.w. pools and streams, with *A. canadensis* in woodland pools, and with *A. triseriatus* in a wooden barrel. Adults taken in all light traps from May to September, maximum catches occurring during August.

Culex salinarius Coquillett. Larvae collected from May to September in ditches, wet areas, pools and ponds on or adjacent to salt marshes; maximum collections taken in September. Larval association with *Aedes cantator* and *A. sollicitans* in pools and ditches on upper salt marshes, with *C. pipiens* and *C. restuans* in f.w. pools on upper salt marshes, with *A. vexans* in f.w. wet areas near salt marshes, and with *C. territans* in f.w. pond near the salt marsh. Adults taken in light traps located within ½ mile from salt marshes from June to September.

Culex territans Walker. (Prior to 1956 identified as *Culex apicalis* Adams.*) Larvae collected from May to September in fresh-water swamps, pools, ponds, streams and ditches; maximum collections taken during July and August. Larval association with *C. pipiens* in f.w. swamps and streams, with *C. restuans* in streams and pools, with *An. quadrimaculatus* and *U. sapphirina* in ponds, with *A. vexans* in f.w. ditches, with *A. canadensis* in woodland pools, and with *C. salinarius* in f.w. pond near salt marsh. A few adults taken in light traps during September.

Culiseta inornata (Williston). No. larvae discovered. One adult taken in a light trap during August 1947.

Culiseta melanura (Coquillett). Larvae found during May 1947 in one breeding place, a fresh-water pool created by the upthrust roots of a fallen tree in a thickly wooded area. No adults taken in light traps.

Mansonia perturbans (Walker). No larvae found. Breeding places revealed by presence of newly emerged adults—all such places being ponds or sandpits filled with ground water and containing dense stands of fox-tails. Adults taken in light traps located near breeding sources from June to September, maximum catches

* Pratt, Harry D. 1956. A Check List of the Mosquitoes (Culicinae) of North America (Diptera:Culicidae). Mosquito News 16(1):4–10, March 1956.

taken during June and July. Observed biting outdoors at dusk.

Orthopodomyia signifera (Coquillett). Larvae found in water contained in rot cavity of tree during August of one year. Adults also taken in nearby light trap.

Uranotaenia sapphirina (Osten Sacken). Larvae collected from July to September in fresh-water ponds in association with *An. quadrimaculatus* and *C. territans*. A few adults taken in light traps during September. No observations on biting.

The prevalence of these species in trap collections for the ten year period 1947–1956 is shown in the following tabulation:

C. pipiens	33,216	57.%
C. restuans	9,751	17.%
A. sollicitans	9,558	16.%
A. vexans	3,020	5.%
A. cantator	1,694	1.%
M. perturbans	471	
C. salinarius	158	
C. territans	55	
An. crucians	26	
An. quadrimaculatus	24	
A. triseriatus	23	
An. punctipennis	22	4.%
A. canadensis	13	
U. sapphirina	10	
A. taeniorhynchus	7	
O. signifera	1	
C. inornata	1	
C. melanura	0	
	58,056	100.%

OPERATIONAL AND SCIENTIFIC NOTES

ANOTHER INSTANCE OF GYNANDROMORPHISM IN *Culex Salinarius* Coq. Roth (1948) [1] reported two cases of gynandromorphism in *Culex salinarius* Coq, which were submitted to this laboratory for determination. These specimens were taken at Fort Gordon, Georgia, on May 27 and June 23, 1943, at resting station number four. These specimens exhibited male antennae and palpi with female abdomens and genitalia.

On May 20, 1957, a shipment of mosquitoes was received at this laboratory from Robins Air Force Base, Georgia, for determination. This material was taken on the night of May 16, 1957, in light traps which are used in routine surveys at many government installations for the determination of indices for mosquito control. Trap number three, in which the specimens were predominantly *Culex salinarius,* yielded another gynandromorph. Other specimens in this collection were normal and consisted of 480 *Culex salinarius,* 23 *Aedes vexans,* 3 *Anopheles crucians,* 2 *Aedes mitchellae,* 2 *Culex quinquefasciatus,* and 1 *Culiseta melanura.*

This gynandromorphic *Culex salinarius* was badly rubbed and had all its tarsal segments lost. The genitalia were withdrawn into the abdominal cavity making it necessary to remove and clear them in KOH to establish the identity of the specimen. The characteristics exhibited by this specimen were female antennae and palpi and a male abdomen and genitalia.

This specimen is now on deposit in the mosquito collection at this laboratory.—Robert Davis, Third U. S. Army Medical Laboratory, Fort McPherson, Ga.

NOTE ON THE OCCURRENCE OF *Aedes atropalpus* (Coq.) IN WESTERN MARYLAND. On August 15, 1957, numerous larvae of *Aedes atropalpus* were found in rock holes at the junction of Muddy Creek and the Youghiogheny River in Garrett County, Maryland, less than 10 miles east of the West Virginia line. Pupae were also abundant and two adults were reared. This area is within the Swallow Falls State Forest and is part of a recreational area designed for visits to Muddy Creek Falls and Swallow Falls. The Youghiogheny River flows into the Monongahela which, of course, joins the Allegheny at Pittsburgh to form the Ohio. It is of interest that this species has been found in the Monongahela Basin. There are published records of its occurrence in rock holes along the Potomac River and along its tributary, the Shenandoah, near Charles Town, West Virginia; along a tributary of the South Fork of the Shenandoah near Rawley Springs (Rockingham County), Virginia; and along the Susquehanna River at Shenk's Ferry (Lancaster County), Pennsylvania. It is abundant in rock holes along the James River near Richmond but has not been reported along the Rappahannock nor the Patuxent.—William E. Bickley

[1] Roth, Louis M., Mosquito News, Vol. 8, No. 4, pp. 168–174.

ASSOCIATION NEWS

Fourteenth Annual Meeting, February 23–26, 1958
Willard Hotel, Washington, D. C.

Hotel reservations should be made directly with the hotel.

Members and their guests will find many attractions in one of the world's most beautiful cities and its metropolitan area. Now is the time to plan for spending some time in sight-seeing. Your committee will furnish information on "What to See in Washington." If you have not yet returned the questionnaire indicating choice of bus tour to Beltsville or Bethesda on February 25, write to Arthur S. Kidwell, Department of Entomology, University of Maryland, College Park.

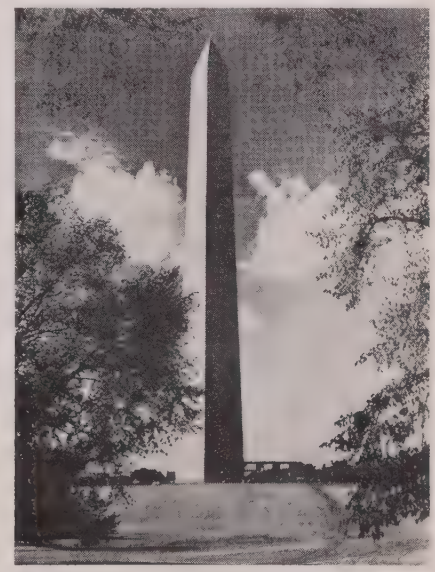
The Virginia Mosquito Control Association will meet with the A.M.C.A.

The Board of Directors of the A.M.C.A. will meet at 10:00 a.m. on Sunday, February 22, at the Willard. Committee Chairmen and other interested members are reminded of this meeting.

Exhibits, both commercial and educational, will be featured at the meeting. Excellent facilities are being provided at the Willard Hotel. All exhibits will be in the south ballroom adjacent to the main meeting room.

Members of the Association are invited and urged to bring and suggest educational exhibits and make contacts with industry and invite commercial exhibits. Funds, after expenses, from commercial exhibits, will be turned over to *Mosquito News* to aid in publication costs. There will be no charge for educational exhibits. Booths will be available for commercial exhibitors at $100.00 each. There will be a limited number of tables available for commercial exhibits at $50.00 each. Detailed information on exhibit space may be obtained from either James R. Foster, or George S. Langford, co-chairmen, Exhibits Committee. Address them at Department of Entomology, University of Maryland, College Park, Maryland.

An interesting and instructive program is being arranged by Cdr. John M. Hirst, Preventive Medicine Unit No. 6, Navy No. 128, F.P.O., San Francisco, California. New information on mosquito research and control will be presented. The program will include many different types of papers and is sufficiently broad to appeal to the entire membership. A few outstanding workers have been asked to present invitational papers. Plans are being made to mail the printed program to members in advance of the meeting.



NEWS AND NOTES

AUSTIN W. MORRILL, JR.

OUR PRESIDENT-ELECT, "MO" HIRST HADN'T BEEN IN HAWAII MORE'N A DAY OR SO when he characteristically found out some interesting local mosquito lore and also characteristically hastened to pass it along to the rest of us, languishing far from that Island Paradise. Commander Hirst says that the mosquito discovered the Happy Isles in 1828, arriving on a sailing vessel, as did the other missionaries of the day. The vessel, the *Wellington,* landed them at Lahina, first capital of Hawaii, on the Island of Maui, long noted among fresh-water seekers of the Pacific islands for its crystalline underground pools. "Makika," says Mo, spread from Maui to the other islands and tried to consolidate its position but has been wrestled to ignominious defeat by vigilant mosquito control people. Mo sends an "Aloha" to all.

ERNESTINE THURMAN SENT A HASTY NOTE VIA TED RALEY, which he has not expanded. Said she, "I'm rushing as usual. I've been invited to present a paper at the Ninth Pacific Science Congress in Bangkok, leaving here on November 8th, by way of Africa." It sounds mighty intriguing and we're awfully happy for Ernestine; she deserves a wonderful trip, and we hope to hear more about it when she returns.

DON M. REES HAS LEFT UTAH COLD; at least, *Utah* will be cold but Don won't. He's gone on a leave of absence to accept appointment as Visiting Professor of Medical Entomology on the staff of the Medical School of the University of Indonesia. The appointment was made through the University of California Medical School, which is assisting in the program of the Indonesian Government to improve medical training in their country. His address will be, with title as above, "University of California Medical School Field Staff, Universitas Indonesia Fakultas Kedokteran, Salemba 6, Djakarta, Indonesia," but fortunately he can be reached, if you forget all that, through the American Embassy, Djakarta.

RALPH C. BARNES OF THE U. S. PUBLIC HEALTH SERVICE has left his former haunts in Atlanta to take up Life in the Rockies. He has recently transferred to Denver, Colorado, where he is now Chief, Communicable Disease Control Services, Region VIII, and his address is Room 517, New Customhouse, Denver.

AND GEORGE T. CARMICHAEL HAS MOVED FROM JACKSONVILLE TO SAVANNAH, GEORGIA, where he is the new Director of the first organized mosquito control program in Georgia. His new address is 12506 Woodley Rd., Savannah, and he writes to Ted Raley, "I'll tell you all about it in D. C. . . . I've really been busy. To start a program in the middle of the season is a job." It surely is, as any of us who have tried it can testify and we hope he had a mighty successful one, and *does* tell Ted all about it so he can pass it on to us and we in turn can give it to you. (Unless you'd like to tell us direct, George? How about it? "News and Notes" would be mighty proud and happy to receive notes now and then from every member who does something of interest . . . and each of us is interested in what the others do.)

IN THE NEIGHBORING STATE OF VIRGINIA, V.M.C.A.'s "Skeeter" reports on the success of surveys to guide control efforts in mosquito control in areas of rapidly growing housing developments. Superintendent GILBERT of Kempsville District hired two high school students with proper qualifications to make a continual survey in his territory of roughly 20 square miles during the period from 10 June to 21 August. More than 9,000 premises were inspected, 8 percent were found to have breeding places and another 17½ percent to have potential ones. At a cost of less than $1,000 these inspections enabled the control crews to know when, where and how much control to apply, a great factor for savings, and in addition gave valuable public relations indoctrination in mosquito control to the homeowners of his district.

IN ANOTHER ISSUE OF "SKEETER," a similar survey in Winchester, Virginia, is reported, in which, while the lagoons at a food processing plant were the obvious source of the principal mosquito population, hundreds of tires in a retreading shop were also found to contain water and to be breeding mosquitoes. Controlling the lagoons would have done little good to the folks who lived and worked near the tire shop and, of course, the personal contact of the survey served to bring to the people concerned their own responsibility for a situation they were no doubt blaming entirely on the conspicuous sources.

ACROSS THE COUNTRY IN ALAMEDA COUNTY, CALIFORNIA, CHET ROBINSON AND MARV KRAMER have been conducting similar surveys and public education and although they are still plagued somewhat by leaky plumbing under houses, their service requests have fallen each month from the number received in previous months and in corresponding months of previous years. This testifies not only to their increasingly effective area control but also to a very effective training of their "public" to detect and avoid or eliminate the back-yard type of breeding so prevalent in uninstructed areas.

Also in California, Les Brumbaugh Reports on his Increasingly Effective Survey and Public Indoctrination Activities, which persuaded one property owner to install 1,400 feet of drain at his own expense, and also led to pleasant statistics such as 33 percent reduction in mosquito adult populations, 50 percent reduction in service requests, and a reduction of premises found breeding mosquitoes to a mere 1 to 3 percent of those inspected. Drainage of irrigated areas is a big problem to Les, as it is in much of California, and one of his projects was to take eight property owners from one area to see and discuss the drainage control work being done in another.

To Return for a Moment to Alameda County, California, Chet Robinson also Reports that his District cooperated with other public agencies on a cattail control program using aminotriazole and dalapon, with which they appeared to have good success and greatly reduced the need for larviciding in the area treated. Marv Kramer and Dr. Ben Keh, of the California Bureau of Vector Control, reported on a survey of the County Water District's percolation ponds, where Clear Lake gnat breeding was found and, following the lead of Don Grant, of San Mateo County, began surveys of biting gnat populations, which point up the fact that communities are increasingly expecting their mosquito abatement organizations to abate other dipterous nuisances as well. Chet's Twenty-Sixth Annual Report, for 1956, contains more detailed information than we can possibly report here, and a lot of mighty fine pictures of his operations, too. If you haven't seen a copy, better ask him for one, because the supply is limited, but it's good, stimulating stuff.

Before we Leave California, Dick Peter's Bureau of Vector Control's very worth-while publication *Vector Views* has an article for November in which Russ Fontaine reports on recent indigenous malaria in Sutter County, California. Four cases occurred during August and the "outbreak" is noteworthy principally because it underlines the fact that we have not really conquered malaria, we have merely driven it out, or back. Wherever the carrier has not been exterminated and a host reservoir is introduced (in this case a summertime farm laborer group is suspected), we can expect our old enemy to attempt to infiltrate back among us. We can't slack off the battle yet.

Herbert P. Herms, Son of the Late Famed Mosquito Control Pioneer in California, reported on his summer campaign to conduct a mosquito breeding survey and canvass and indoctrinate the householders of his Sutter-Yuba Mosquito Abatement District. Ten teams of two members each were formed from among the members of a 4-H Club and in addition to visiting homes, various mass media of information were used.

Bleabay Bedell and James Nimley from the Mosquito Control Districts of Liberia and now at the University of Kansas, whom we mentioned last issue as having visited Don Grant and others, have now become full-fledged members of our Association and we hereby take occasion to welcome them into the fold, or to keep our metaphor straight should we say flock? We hope that their associations with us strange birds who control mosquitoes will be as pleasant and productive for them as we think they are ourselves.

Also to be Welcomed into Our Ranks (Those Metaphors Again!) are Owen Hugh Graham, late mosquito control man for the Army in Panama and now with U.S.D.A. in Kerrville, Texas, and Cdr. (Dr.) Richard T. Holway, new Insect Vector Control Officer for the Navy on the Pacific Coast.

While we are on the Navy, you Might be Interested to Know that the Navy Field Research Laboratory has recently published the results of development studies by a unit at Camp Lejeune, N. C., which resulted in a practical, inexpensive rig for dispersal of insecticides by helicopter. This was reported to be easily constructed of parts available at any repair and overhaul facility, except for the nozzles, and does not interfere in any way with the navigability of the helicopter. These studies are of interest to all of us, for when aircraft dispersal by means of craft capable of close, low-level maneuvering, is finally developed, it may well provide the answer which many of us are seeking to the knotty problem of control in inaccessible areas.

Speaking of the Navy, ye Assistant Sub-Editor for News and Notes Hates to Call Attention to Himself (however modestly!) But . . . feels he must reprint the following from a Stockton (Calif.) paper: "*Dr.* (!) Austin Morrill, Entomologist for the 12ND Public Works Office at San Bruno, visited the Annex last Wednesday and Thursday. Assisted by Charles Taussig, Annex Sanitation Specialist, Morrill was studying the invective control measures here." No swearing now, . . . please!!

Well we Have Another Bit of News about Don Grant, Too. He's Been Busy for A.M.C.A. as Pacific Southwest Representative and has sent out a very fine news letter to some 80 or more administrative and technical people in control agencies, public health personnel, professional, research and academic people in universities and research centers, representatives of chemical and equipment firms dealing with mosquito control operations, and others. His letter is a strong invitation to join, if they are not now members, and to participate more actively if they are (especially in the matter of getting new members). It is too

early to count the returns, but if the letter doesn't result in at least a goodly handful of new subscriptions to *Mosquito News,* we miss our guess.

WE HAVE RECEIVED THREE WRITE-UPS FROM THE I.C.A. CONCERNING THEIR PEOPLE IN MOSQUITO CONTROL and we reprint portions of them here, since many of our members may know these mosquito control workers and be interested to hear about them.

THE FIRST ONE IS DR. MELVIN E. GRIFFITH, A.M.C.A. MEMBER, FORMERLY OF THE UNIVERSITY OF OKLAHOMA and the Oklahoma State Department of Health's malaria control project. Dr. Griffith, like the Dr. Butler we reported on last issue, is following in the footsteps of the Thurmans and pushing forward the great accomplishment of malaria control in Thailand. After spending six years as chief malaria adviser to the Thai Ministry of Public Health, he returned in August with his family for some home leave. When they returned in September, it was to an expanded program to which, during his period in office, has been added the responsibility for advisory assistance to Laos and the further stimulating and developing of the intercountry anti-malaria coordination among Thailand, Cambodia, Laos, Vietnam and Malaya on which HARRY STAGE and others have labored. Dr. Griffith reports that the work is beginning to show real progress.

Mr. John W. Shipp and his family have returned to the United States after spending two years in Libya with the I.C.A. Mr. Shipp was assigned to Tripolitania as Regional Sanitarian. Mr. Shipp has had 12 years of foreign experience, having served with U.N.R.R.A. in Egypt and Greece and with the I.C.A. in Burma and Pakistan. After visiting their several relatives in Wisconsin and Texas, the Shipps plan to leave for another overseas post.

Mr. Edward Najjar, parasitologist from Virginia and West Virginia, has also returned for a visit to the United States, after two years' work on malaria control in Ethiopia. After visiting his and his wife's parents, the Najjars will return to Ethiopia. Mr. Najjar was born in Beirut, Lebanon, and lived there until he was eighteen, graduating from the American University there. He also holds a B.S. degree from Concord College in West Virginia and an M.S. from the University of North Carolina. He speaks six languages and in addition to a period with the county health department and the Mullens Medical Laboratory in West Virginia, he has served in the I.C.A. mission to Iran. Altogether a rather valuable man and, perhaps, a good prospect for Good Neighbor Club membership in A.M.C.A. as a starter! Any sponsors?

FRED STUTZ SENT US A LETTER AND SOME INTERESTING CLIPPINGS. The clippings are a sort of suspense story about a riled-up resident who took some pot shots at a mosquito spray plane and not only brought it down (on its wheels, but down) but also critically wounded a passenger who, ironically had gone through World War II and the Korean War as a combat pilot, "without a scratch." The assailant, who claimed to be a "sensible fellow" (!) and to "know right from wrong," nevertheless fired his gun at the plane but "didn't intend" to hit it. (Amazing, these people who shoot off guns but don't "mean" to hit anything!) He claimed the plane had made four or five passes, but the pilot said it was on its second run. Seems as if in this day of trucks, passenger planes and other noise makers, that even four or five passes would hardly excuse this fellow. He obviously wasn't bright enough to understand mosquito control, anyway! Fred tells us the fellow is out on bail awaiting final sentencing and he'll give us the end of the story when it happens. (In the Philippines, once, the Huks fired at one of our spray planes and the Philippine Air Force went right over and fired back. Got 'em, too.)

FRED ALSO SENT HIS 1956 ANNUAL REPORT FOR DADE COUNTY ANTI-MOSQUITO DISTRICT. It's an interesting and illuminating report and points out the expansion that is happening to mosquito control in the addition of the *Culicoides,* tendipedid and ordinary house fly problems. Fred also gives a bow of acknowledgment to the construction men and their housing "developments" which are changing the landscape around so many American cities now, but points out that while the landfilling is useful in terms of mosquito control, it does not end the swamp problem and may make it worse by leaving inaccessible pockets or moving more population into areas the mosquitoes formerly had to themselves, sort of. The builders have even taken over the airports so that Fred says he's got a real problem finding a take-off place for his spray planes.

STAN CARPENTER HAS ARRIVED FOR HIS SECOND TOUR OF DUTY AT THE SIXTH ARMY MEDICAL LABORATORY, Ft. Baker, California, a part of the Presidio of San Francisco. He brings us word that Capt. R. A. HEDEEN has joined the staff at Ft. Sam Houston, Texas, the Medical Field Service School. Col. Carpenter is looking around for a house and is planning (we Californians hope) to settle down here for keeps. While we're at it . . . we might as well start our Who's Who with him:

STAN WAS BORN IN OLD KENTUCKY in 1904 and went to school there and in Tennessee, getting his Master's at the University of Tennessee and then going on for his further work at Ohio State. He was Medical Entomologist for the Arkansas State Health Department from 1937 to 1941, and published the still-definitive *Mosquitoes of Arkansas.* In 1941 he entered the Army as a Captain and saw duty as entomologist of the Seventh Corps Area, the Persian Gulf Command, the Fourth Service Command Laboratory (Atlanta, Ga.), the Ninth Service Command Laboratory (San Francisco), the Second Army Medical Laboratory (New York), the Caribbean Army Com-

mand and the Laboratory of the Medical Field Graduate School at Walter Reed Hospital in Washington, D. C. He also worked or travelled on advisory tours in Western and Central Africa, Egypt, Iran, Kuwait, Central America, Western Europe, Japan and Korea, so you can see that there are very few places mosquitoes go that Stan hasn't been. His *Mosquitoes of North America* is, of course, a modern classic. He is a member of the Entomological Society of America, the A.M.C.A. the American Society of Tropical Medicine and Hygiene, the Entomological Society of Washington, D. C., the California Mosquito Control Association and other learned societies, but he speaks perfectly understandable English.

Don Collins, Our Editor, has heretofore forestalled our writing anything laudatory or otherwise about him, not by censoring it out but by the simple process of not furnishing it. We finally cornered him and he gave up and promised not to depart too much from his policy of non-interference with associate editors' contribution. If this appears in print, you'll know we either eluded him, or he kept his word. So: . . . Don was born, not in the Education Building of the Empire State but in Union Springs, N. Y., wherever *that* is. He attended Hobart College and then received his M.S. and Ph.D. from Harvard in 1930 and 1933, respectively. While in college, he not only majored in chemistry and biology but studied a great deal of English and history. He has had a highly varied career, which included field work with the New York State Agricultural Experiment Station and the U. S. Department of Agriculture, teaching at Hobart College, research at Cornell, being chief of the agricultural chemical research for Pennsylvania Salt Co. and finally State Entomologist of New York. He is author of fifty or more papers on subjects ranging from codling moth, bark beetles and Dutch elm disease, through ticks, blackflies, mosquitoes, etc., to aerosols, insect physiology and other abstract and higher level matters. He is a past member of the Council of the American Association for the Advancement of Science as well as a Fellow of that organization, past President of the Albany club of Sigma Xi, past President of the Harvard Association of Eastern N. Y., member of the Entomological Society of America, the Northeastern Mosquito Control Association, the Northeastern Forest Pest Council, and several others. (He is also a member of the American Mosquito Control Association, in case you didn't know it—M.G.S.) His hobbies are skin diving, swimming, rose culture and painting, a mixture of the athletic and the thoughtful—and he must spend long hours on *Mosquito News*. . . . We'd tell you more but he's hell on deadlines. . . .

New Member Owen Hugh Graham, whom we mentioned earlier, was born in Thorndale, Texas in 1917 and received his B.S. and M.S. from Texas A. and M. College. He began his work in entomology with the U. S. Bureau of Entomology and Plant Quarantine, working on arthropod transmission of plant virus diseases and on the control of the alfalfa weevil. In 1942, he transferred to the investigation of insects affecting man and animals but in less than a year the Army snatched him to be a First Louie in the Sanitary Corps. He was overseas, in New Guinea, for two and a half years, ending up in the Philippines with the Fifth Malaria Survey Unit (which also worked on schistosomiasis, fly control and such). After the war, for four years he was with the Livestock Insects Laboratory at Kerrville, Texas, and then for six years was entomologist for the Headquarters of the U. S. Army Caribbean Command, stationed at Ft. Clayton in the Canal Zone. He is now the Assistant Station Leader of the U.S.D.A. Kerrville Lab. Welcome to A.M.C.A., Hugh!

Another Texan (by Adoption) is Professor Osmond P. Breland of the University of Texas in Austin. He was born in 1910 in Decatur, Mississippi and attended Mississippi State for his B.A. degree, moving on to Indiana University for his doctorate. From 1936 to 1938 he taught at North Dakota State College in Fargo, but in 1938 he saw the light and moved to Texas. He has also done summer teaching at C.C.N.Y. and Sioux Falls College (South Dakota). From 1943 to 1946 he was with the Sanitary Corps of the Army and is still an active reservist like many another shining light in entomology and in mosquito control in particular. He is author of a large number of technical and semi-popular articles and of four text books on zoology and biology. His hobby is stamp collecting, so any of you collectors who don't have a series of Texas stamps, here's your chance. (What's that? Texas doesn't *issue* its own stamps and coins? Oh, come now!)

Recently, we Told You How One of Our Well-Known Members Left His Abatement District to Come to the Rescue of the Thirteenth Naval District's Public Works Office and Their Insect and Rodent Control Program. Well, to see how well you read this column, we'll let you guess who he is by reprinting here the dope about him he had to turn in when he reported aboard in Seattle:

He was born in 1914 in Connell, Washington, and was raised on farms in Washington and Oregon. He took his pre-medical work at the University of Washington (pre-med being, as you all know, also pre-entomology) and later went to the University of Arizona, where he majored in entomology and economic zoology and received his B.S. in 1941. He was in the Sanitary Corps of the Army from 1942 to April 1946, during which time, among other assignments, he was active in the campaign to control bubonic plague in Dakar, French West Africa, when DDT was

used for the first time (to control plague) by eradication of fleas in that city of 150,000 people. After the war he was a college instructor for two years and then was recalled into the Army. In 1949 he transferred his commission to the U. S. Public Health Service and in this capacity served as consultant to the Oregon State Board of Health. For some four years he was in the pest control business but sold his share to his partner and became director of the Lane County Mosquito Control program, which position he has held for the past four years. In June of this year, he left Oregon to become the entomologist for the Thirteenth Naval District. Oh, *now* you remember? Yes, MILT BUEHLER.

THE JOSEPH AUGUSTIN LEPRINCE AWARD, consisting of a bronze medal, a certificate and an honorarium of $500, is now presented every 3 years by the American Society of Tropical Medicine and Hygiene to a person for outstanding accomplishment in the field of malaria. This year the honor was bestowed upon Dr. Louis L. Williams, internationally known for his work in malaria control. At the start of World War II he organized and developed the office of Malaria Control in War Areas and has become known as the father of malaria eradication in the United States. After he retired as chief of the International Health Division, U.S.P.H.S., in 1953, he joined the staff of the Pan American Sanitary Bureau as consultant and here his fight against malaria continues on an even broader scale.

GENE WOODS EARNED A GOOD, BIG WRITE-UP IN THE KENTUCKY DEPARTMENT OF AGRICULTURE BULLETIN for October, when two columns of the front page were given over to a description of his highly successful 1957 mosquito control campaign. During the second year of air spray operations, 113,200 acres were aerially treated, using their own spray plane, at a cost of only 48¢ per acre. In addition to their own work, the State's abatement program assisted those of several counties and of the Calvert City area. We got this news from faithful BILL BICKLEY, who is always eager to see that other people get publicity for their good work. We'd be glad to hear more about you from *You*, GENE, from time to time. How about it? (And how about it, you other guys who modestly hide your lights under bushels?)

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REVIEWS AND ABSTRACTS

Three-year Investigations of Mosquito Breeding in Natural and Impounded Tidal Marshes in Delaware. By R. F. Darsie, Jr. and P. F. Springer. Tech. Bull. 320, Univ. Del. Agric. Expt. Sta. 65 pp. 1957. An investigation of mosquito breeding in natural and impounded tidal marshes in Delaware was conducted from 1953 to 1955. Study areas included two natural marshes and two fresh-water impoundments, one completed in 1939 and the other after the first summer of study. The impoundments were designed to improve waterfowl habitat, and consisted largely of open expanses of water several feet in depth containing submerged plants with marginal stands of emergent vegetation.

In the tidal marsh, the mosquitoes dipped in greatest numbers were *Aedes sollicitans* and *Aedes cantator,* the two most important pests in the area. They were followed in abundance by *Culex salinarius* and *Anopheles bradleyi.* However, numbers varied considerably each year. *C. salinarius* was the species taken most commonly in 1953, *A. cantator* in 1954, and *A. sollicitans* in 1955. Breeding in the tidal marsh was not uniform, but occurred mainly at the upper edges near the mean high tide level, in sites characterized by growths of saltgrass, saltmeadow cordgrass, and mixtures of the two alone or with saltmarsh cordgrass.

Permanent impoundment of fresh water in the mosquito-breeding zone along the mainland reduced salinity and prevented frequently fluctuating water levels. As a result, the two important saltmarsh *Aedes* pests were almost entirely eliminated due to lack of suitable oviposition sites. *An. bradleyi* also was markedly reduced; however, *C. salinarius,* a broadly adapted species, continued to thrive. Impoundage favored breeding of certain fresh-water mosquitoes, including the permanent-water species, *Anopheles quadrimaculatus, Uranotaenia sapphirina,* and *Culex restuans,* and a flood-water species, *Aedes vexans,* which occurred only after rises in the pond level resulting from heavy rains. By reason of their daytime resting habits, generally limited flights, non-biting of humans, or the smaller numbers produced, these species, compared to the salt-marsh *Aedes,* were of less or no importance as pests. Most breeding occurred in woods edge, phragmites, cattail, switchgrass and, during the first year after flooding, swampdock.

In the impoundments, maintenance of a high, fairly stable water level, which flooded emergent vegetation, resulted in the production of large numbers of permanent-water mosquitoes (*Culex, Anopheles,* and *Uranotaenia*), but few *A. vexans.* High water also favored submerged pondweeds, which are heavily utilized by waterfowl. Recession of the water from the vegetated margin during the summer caused the growth of moist-soil annual and perennial plants attractive to waterfowl and muskrats. Under a drawdown condition, fewer permanent-water mosquitoes were produced, but subsequent reflooding before late fall resulted in larger numbers of *Aedes.* Lowering of the water level below the roots of host plants each summer for several weeks or more effectively prevented the successful breeding of *Mansonia perturbans.*

The principal mosquitoes taken in the light trap were *A. sollicitans, C. salinarius,* and *An. crucians* complex (probably mostly *bradleyi*). No one species was clearly dominant, *C. salinarius* being the most common in 1953, *An. bradleyi* in 1954, and *A. sollicitans* in 1955. However, *A. sollicitans* accounted for almost all of the daytime biting. In the *Mansonia* traps in Shearness Pond during 1955, the average emergence was 2.6 adults per square foot of cattail marsh, or 0.5 adult per cattail stalk.

Prior to impoundment, the principal wildlife utilization of the tidal marshes was by several species of surface-feeding ducks, shorebirds, rails, muskrats, fish, diamond-backed terrapins and blue crabs. Following fresh-water flooding, much larger numbers of waterfowl and certain other water birds utilized the ponds. Only a few birds showed considerable declines. Muskrat populations were restricted by the high water level in the impoundments, but many species of fish continued to thrive and several new species were noted. Fresh-water flooding eliminated diamond-backed terrapins and blue crabs, but bullfrogs and snapping turtles appeared.

Because of the small acreage of the impoundments in relation to the surrounding tidal marsh, the decline in certain wildlife was of little importance. The net effect of fresh-water flooding was a significant reduction of nuisance mosquitoes in an important breeding zone and greatly enhanced conditions for waterfowl and certain other marsh birds.

To minimize the mosquito nuisance and to provide conditions favorable for waterfowl in impoundments, it is recommended that, where possible, a combination of the flooding and drawdown management be practiced.—Authors' abstract.

The Behaviour of Larvae and Pupae of *Aedes aegypti* (L.) in Light and Temperature Gradients. By T. A. Omardeen. Bull. Ent. Res. 48 (2):349–357. 1957. This paper reveals the interesting fact that while second and third stage *aegypti* larvae initially move away from light, they actually have no light preference and will gradually move back towards light, whereas fourth stage larvae and pupae, especially the latter, exhibit definite photophobia. While third and fourth stage larvae and pupae of *aegypti* prefer zones of 28–32° C., it is a curiously interesting observation that more second stage larvae congregate in the

23–27° than in the 28–32° C. zone.—Jack Colvard Jones, National Institutes of Health, Bethesda, Md.

THE INFLUENCE OF TEMPERATURE AND HUMIDITY UPON THE ACTION OF INSECTICIDES. I. DURING THE POST-TREATMENT PERIOD. II. TEMPERATURE DURING THE PRE-TREATMENT PERIOD. By A. B. Hadaway and F. Barlow. Ann. trop. Med. and Parasitol. 51(2):187–193; 194–200. 1957. Two to three day old, blood-fed, adult female *Aedes aegypti* and *Anopheles stephensi* were treated with DDT, gamma-BHC, dieldrin, and diazinon using 2 different methods (by application to dorsal thorax with Kerr microburette or by placing adults on filter papers containing deposits of insecticides). As expected, fewer mosquitoes were killed at a given dosage of DDT when the post-treatment temperature was increased from 25 to 30° C. (i.e., there is a large negative temperature coefficient). With dieldrin and diazinon, kills tended to increase with post-treatment temperatures (i.e., there is a small positive temperature coefficient). With BHC there was no change in kill with post-treatment temperature increase. The really striking new fact in the first article is that great humidity differences (20 to 95 percent) apparently have no effect whatever on kill with any of the insecticides. The second article shows that where age and nutritional status are controlled pre-treatment temperatures (25 or 30° C) have no effect on susceptibility of *Aedes* to DDT, dieldrin or BHC.—Jack Colvard Jones, National Institutes of Health, Bethesda, Md.

WORLD HEALTH ORGANIZATION. 1956. Malaria. World Health Organ. Bul. 15(3/5):361–862. Price $6.00. One should not miss this outstanding compilation on malaria. The ideas of some of the most active students of malaria are woven together to cover the disease from a global viewpoint. Such broad phases as control, eradication, resistance, vectors, epidemiology, distribution and antimalarials are among the subjects included.

Some of the papers of particular interest to mosquito workers are as follows: G. MacDonald was concerned with the theory of malaria eradication. He analyzed the process of elimination of malaria, the detection of residual foci and the reintroduction of the disease. Surveillance in Ceylon, Thailand and in Taiwan was discussed by L. F. Gunaratna, L. Ayurakitkosol and M. E. Griffith, and C. T. Ch'en and K. C. Liang, respectively.

Several authors contributed on the problem of resistance of anophelines to insecticides. J. R. Busvine dealt with the meaning of insecticide resistance and with measurements of the susceptibility of different mosquitoes to insecticides. In Greece, G. A. Livadas and K. Thymakis indicated that the tendency for anophelines to acquire resistance to DDT appeared to be continuing. G. Belios and G. Fameliaris found *Anopheles sacharovi* Favr. larvae to be resistant to chlordane and dieldrin in parts of Greece, but, although DDT was more generally used no appreciable resistance to DDT was noted. *A. sundaicus* (Roden.) resistance to DDT in Java was reported by C. Y. Chow and H. T. Soeparmo.

G. Giglioli compared the biological variations of *A. gambiae* Giles with those of *A. darlingi* Root. Studies on the ecology of *A. claviger* (Meig.) in the Middle East were described by G. Gramiccia.

The vectors of malaria are of particular interest. M. Farid noted the involvement of *A. sergenti* (Theo.) in malaria eradication programs east of the Mediterranean and Botha de Meillon discussed malaria vectors in Africa. Distribution of the vectors in Africa and Madagascar was discussed by J. Hamon, J. P. Adam and A. Grjebine.

The next series of papers concerns the epidemiology and control of the disease in different areas. G. Macdonald reviewed the subject of malaria in equatorial Africa, P. M. Bernard in tropical Africa, D. Metselaar in New Guinea, J. de Zulueta in Sarawak, Brunei and Borneo (one paper in collaboration with F. Lachance), H. M. Archibald in northern Nigeria. G. Joncour describes control in Madagascar, M. Ciuca in Romania and C. Simic in Yugoslavia.

Malaria control by drugs was discussed by G. Houel who described the use of different drugs for mass treatment in Morocco. H. M. Archibald and L. J. Bruce-Chwatt described the suppression of malaria in Nigerian school children.—Helen Sollers, Plant Pest Control Div., ARS, U. S. Department of Agriculture.

DAYTIME RESTING PLACES OF *Anopheles minimus* IN RURAL HOUSES OF TAIWAN (FORMOSA), CHINA. By Po-Taun Tseng, Hsi-Hauan Chen, and D. J. Pletsch. J. Formosa med. Assoc. 55 (12):22–28. 1956. (In English, with English and Chinese summaries.) A total of 14,466 specimens of female *A. minimus* collected in 757 rural houses throughout various parts of Taiwan were analyzed to study their daytime resting places in human dwellings. Of the 7 types of rooms or house areas classified, bedrooms are preferred as anopheline shelter, followed by store rooms, sitting rooms, kitchens, bathrooms, toilet rooms, and under eaves, in the order named.

Of the 16 types of microhabitats classified, the areas listed as "underneath bed," "roof, inside," "underneath furniture," and "wall below 1 meter" are the 4 most preferred resting places.

It is estimated that of the total number of the mosquitoes found in a house 14.68 percent rest on the surfaces of objects which are not treated with ordinary applications of residual insecticides. It is suggested that in Taiwan, the examination of areas "underneath beds" will suffice for sampling of an *A. minimus* population in human habitations.—Authors' summary.

THE SUSCEPTIBILITY OF *Aedes aegypti* LARVAE OF DIFFERENT AGES TO DDT AND DIELDRIN, AND THE RELEVANCE OF THE RESULTS TO THE FORMU-

LATION OF STANDARDIZED SUSCEPTIBILITY TESTS FOR MOSQUITO LARVAE. By A. H. Parker. Ann. trop. Med. and Parasitol. 51(2):201–215. 1957. In this important study, uniformly reared *Aedes aegypti* larvae of all stages and known ages were exposed as batches of 20 within 100 cc of 5 different concentrations of DDT and dieldrin (acetone suspensions in distilled water) at 24° C for either one hour or for 24 hours, both followed by tap rinses and 24-hour recovery periods with food and water. The short exposure requires this recovery period, the long one does not. Determinations of mortally affected larvae were made with a slightly modified Burchfield-Hilchey-Storrs apparatus (when affected, larvae do not initially move away from the light). According to the author of this paper 24-hour mortality readings with either long or short exposures give a reliable index of eventual mortality to both DDT and dieldrin. The long exposure method could not be used for first and second stage larvae due to high control mortality with distilled water.

The data show, somewhat unexpectedly, the intriguing fact that with both insecticides, second day old first instars were the most susceptible of all stages. As expected, those about to pupate were the least susceptible of larval stages.

With both short and long exposures it was found that the median lethal concentration significantly increased with each day of development. The total variation with long exposures was less than with short ones. Third stage larvae were significantly less variable than the fourth stage with either exposure. Inherent variation was found to be greater with DDT than with dieldrin.

Parker found no evidence of changes in *Aedes* susceptibility at larval molts (a fact true also for *Anopheles quadrimaculatus* when these larvae are exposed to dilute formulation DDT—unpublished data of the reviewer). A significant change in susceptibility at the molt apparently occurs only with relatively higher concentrations of toxicants.

Parker suggests for bioassay studies with *aegypti* the use of third stage larvae and 24-hour exposures.—Jack Colvard Jones.

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